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Interventional Procedures

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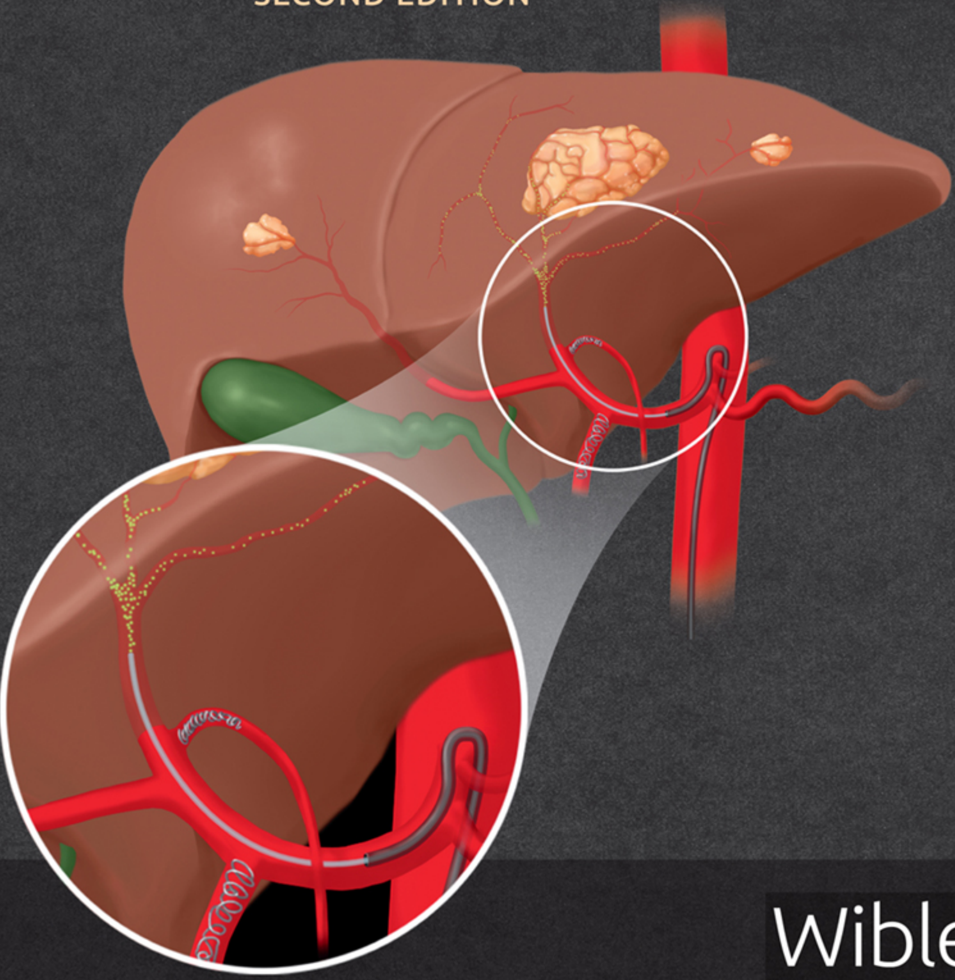

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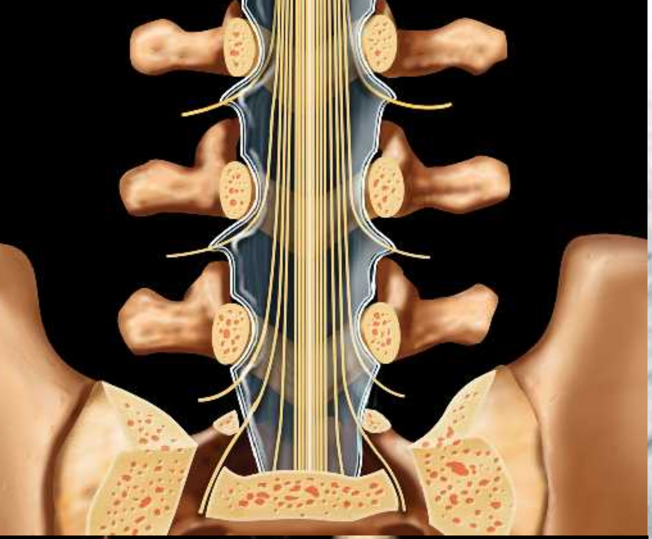

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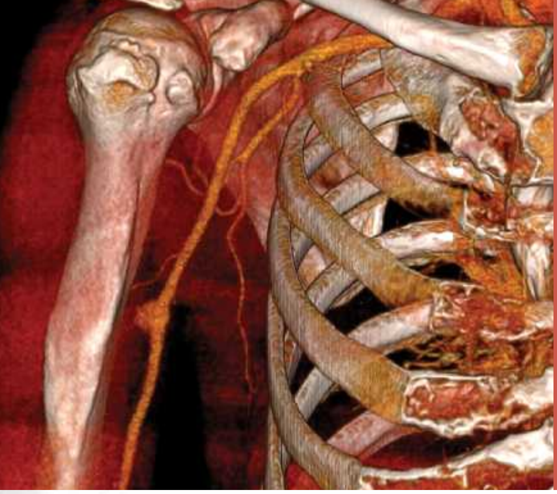

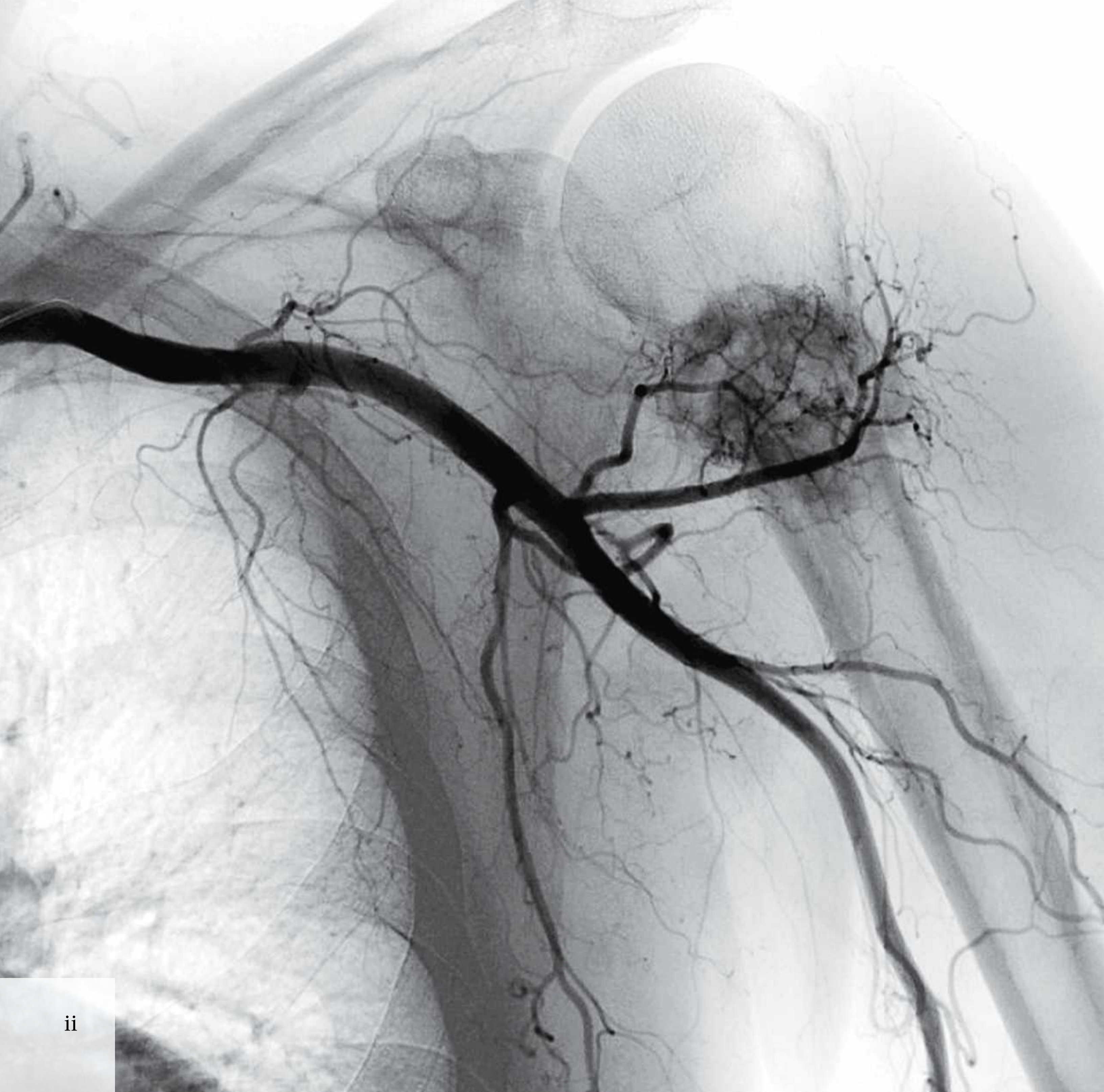

Diagnostic Imaging

Interventional Procedures

SECOND EDITION

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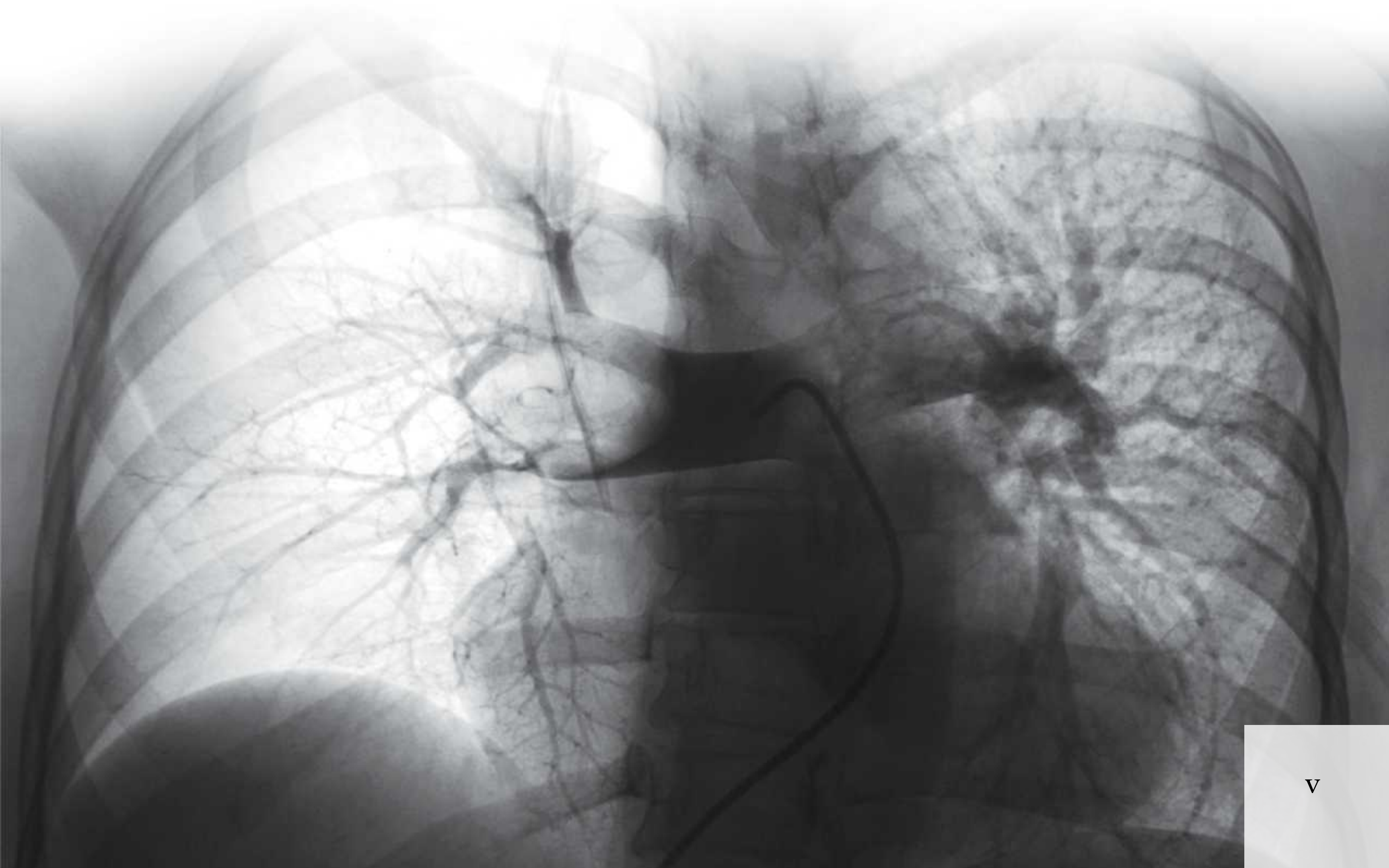
Dedication

To Helen, Brayden, Brighton, and family not-so-extended,
for your faith, support, and encouragement.

To friends and mentors, for years of enlightenment
and inspiration.

And to the United States Peace Corps.

BCW



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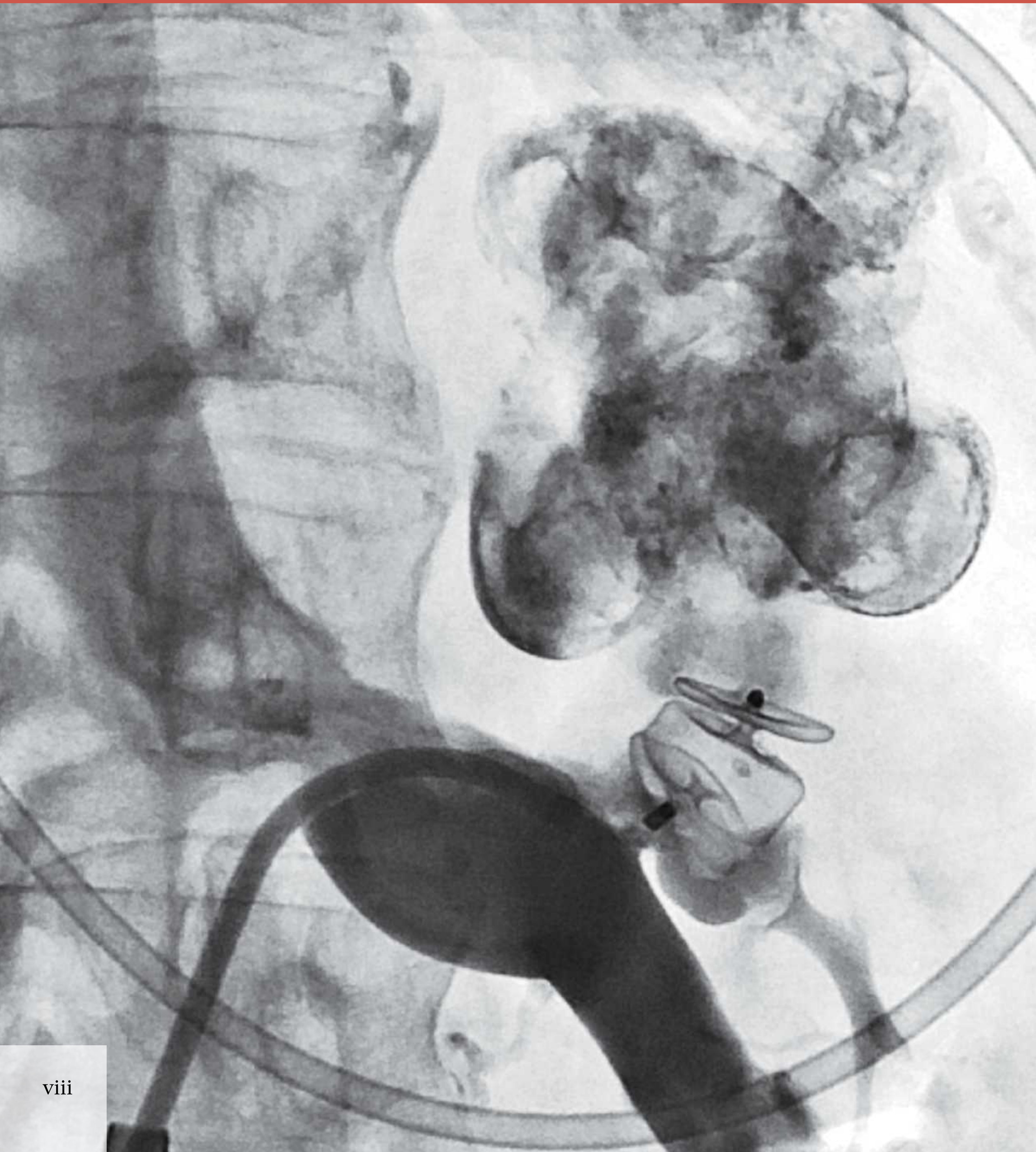

Preface

Welcome to *Diagnostic Imaging: Interventional Procedures*, second edition! Designed as a "how-to" guide and searchable reference, this second edition has been authored to be instrumental to trainees and seasoned interventionalists. The format remains true to the first edition created by T. Greg Walker, MD, FSIR and his team. The text encompasses the extensive scope of vascular and nonvascular procedures expected of a busy interventional practice, covering topics in a comprehensive and detailed fashion. Succinct text, bullet points, and subdivided chapters also allow rapid search of pre- and postprocedural concepts.

Updates in our second edition include over 800 new high-resolution case images and numerous new full-color graphics. Procedures described within the text are illustrated with step-by-step case examples that have been updated and optimized. Procedure-specific references, interventional techniques and equipment, and expected procedural outcomes have been updated as well. Additionally, new chapters have incorporated supplemental topics such as procedural medications, lumbar puncture, celiac plexus block, and sacroplasty.

Diagnostic Imaging: Interventional Procedures, second edition includes contributions from several first-edition authors practicing at Massachusetts General Hospital, plus new physician authors from Johns Hopkins University, University of Pennsylvania, University of Utah, University of Missouri-Kansas City, and University of Wisconsin, in addition to several seasoned authors who have found their way to private practice. I am eternally grateful to these authors for their dedication, professionalism, and hard work. Additional credit and gratitude goes out to the team of editors and illustrators at Amirsys/Elsevier, setting the *Diagnostic Imaging* series of textbooks apart from any others currently available.

I am especially grateful to Dr. Walker, who recommended I lead authorship of the second edition of his text. After years as a team leader for Amirsys' RADPrimer, a contributing author to STATdx, and director of our interventional radiology curriculum and medical student rotation, I have always found case examples to be one of the best learning tools for our trade. The opportunity to update a textbook flush with case images and outstanding graphics appealed to me greatly, and I have since found the process to be a rewarding experience. I hope that you will find the second edition of *Diagnostic Imaging: Interventional Procedures* to be a valuable addition to your practice.

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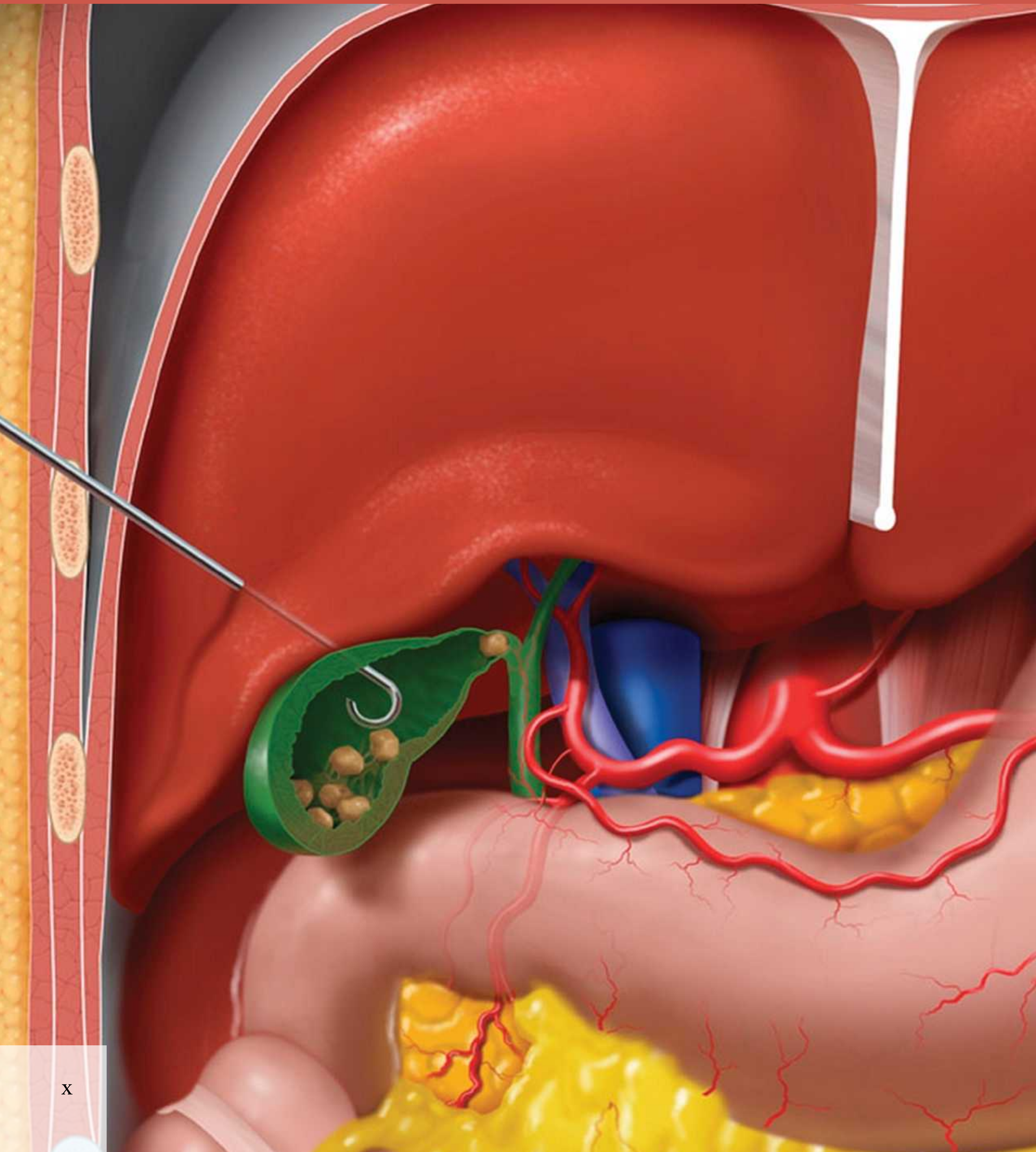

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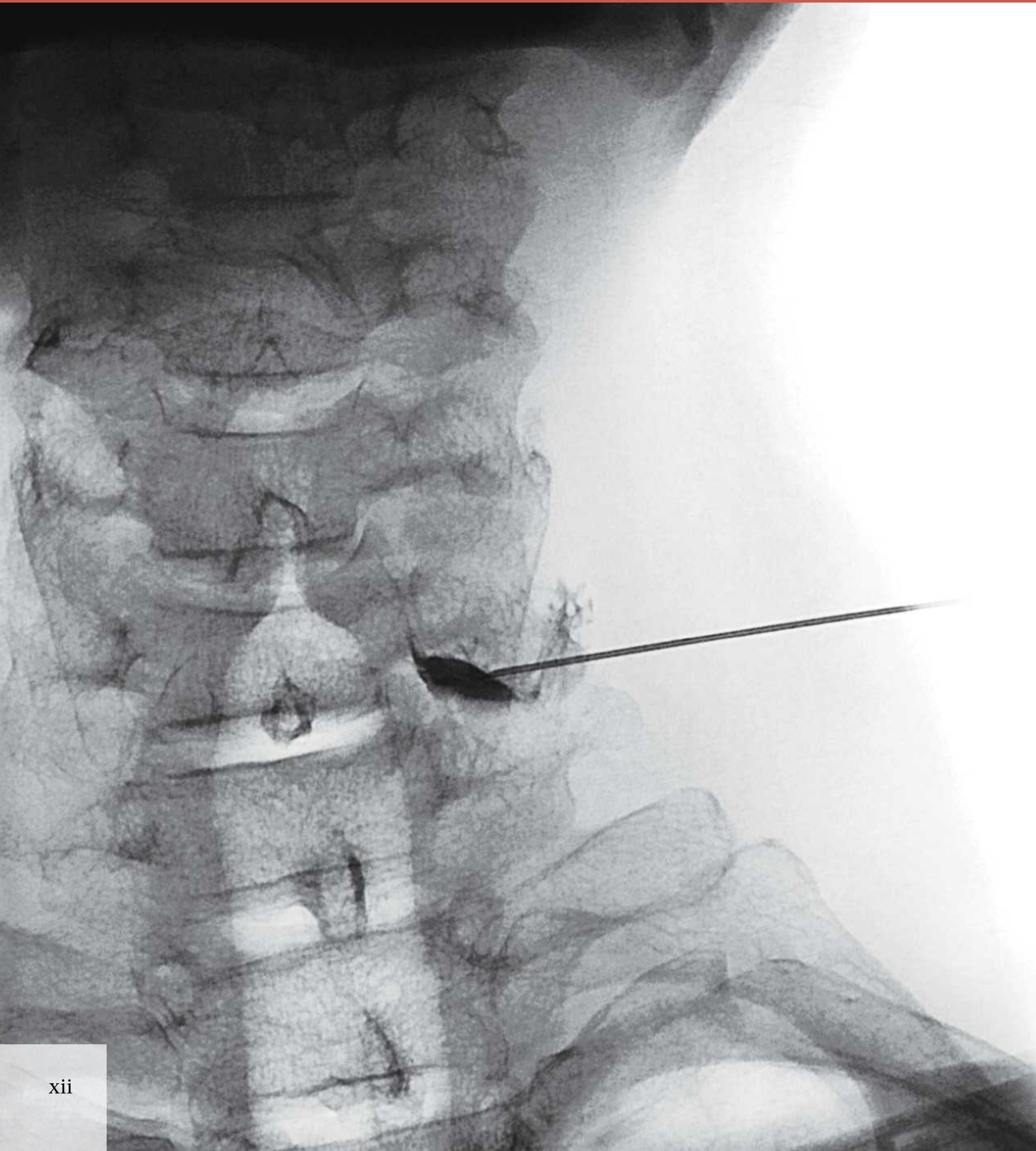

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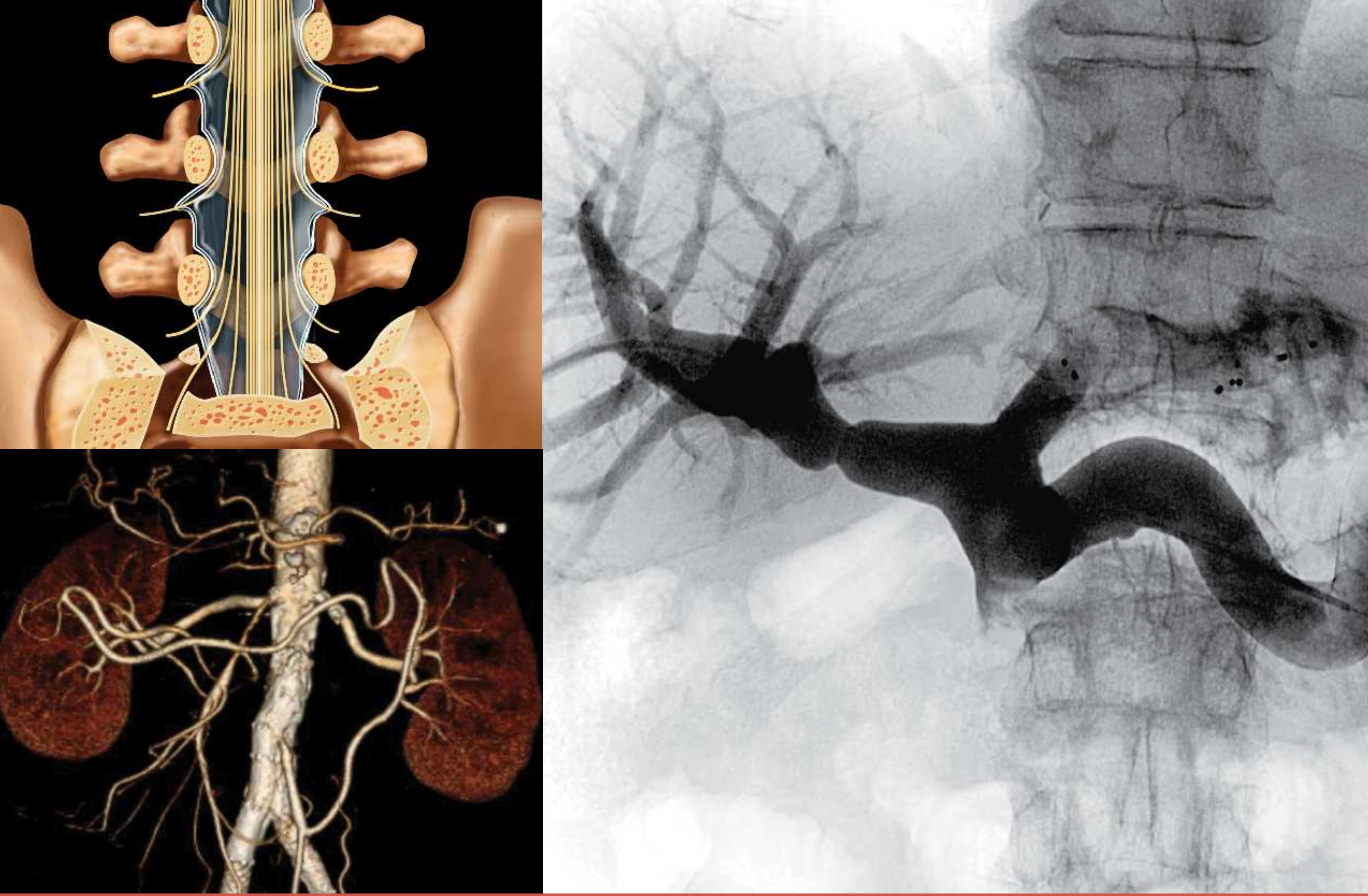

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SECTION 1

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KEY FACTS

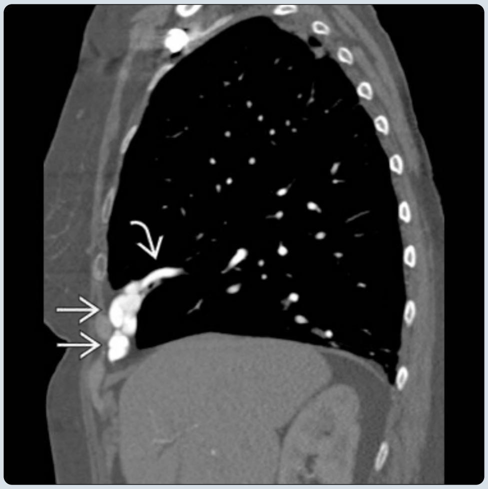
UTILITY OF PREPROCEDURE IMAGING

- Mapping of normal & abnormal anatomy
- Obtaining physiologic information
- Used for planning of interventional procedures
  - Determination of appropriate device type & size

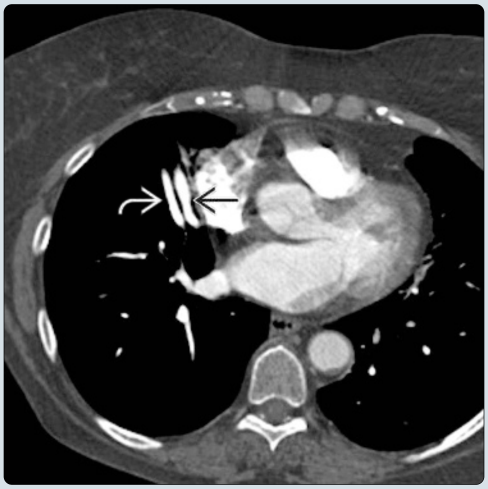
PREPROCEDURE IMAGING OPTIONS

- **Ultrasound**: Includes grayscale, color Doppler, intravascular ultrasound
  - Advantages: Noninvasive, excellent tissue contrast
  - Disadvantages: Window limits, operator dependent
- **Intravascular ultrasound**: Used with angiography
  - Advantages: Depicts intraluminal characteristics
  - Disadvantages: Invasive, added expense & time
- **Echocardiography**: Includes transthoracic & transesophageal echocardiography
  - Advantages: No radiation or contrast agents needed
  - Disadvantages: Limited 3D capability
- **CT**: Includes CTA/CTV
  - Advantages: Excellent 3D spatial resolution
  - Disadvantages: Ionizing radiation, requires contrast
- **MR**: Includes MRA/MRV
  - Advantages: Best tool for tissue characterization
  - Disadvantages: Decreased spatial resolution, expensive, time intensive
- **DSA**: Includes cone beam CT
  - Advantages: Guidance for vascular interventions
  - Disadvantages: Invasive, requires contrast
- **Radionuclide scintigraphy**: Includes scintigraphy, 3D single-photon emission CT, and PET
  - Advantages: Physiologic information
  - Disadvantages: Radioisotope exposure

PAVM: Preprocedure Planning (CTA)

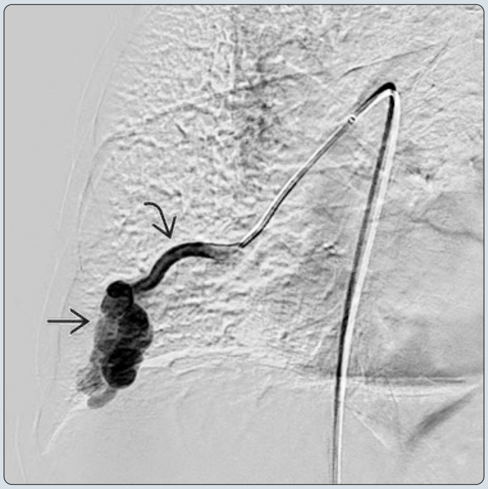


PAVM: Preprocedural Planning (CTA)

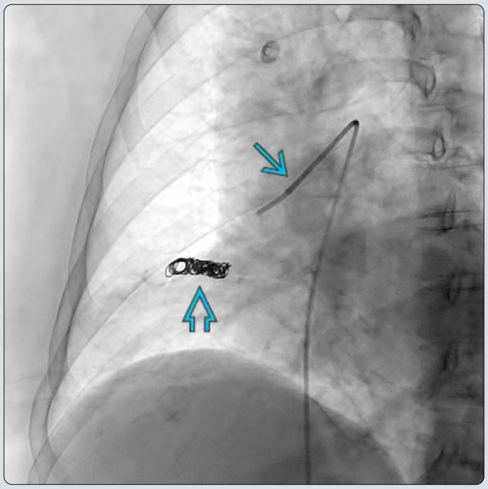


(Left) *Sagittal CTA of the chest demonstrates a prominent pulmonary arteriovenous malformation (PAVM) ➡ with a discrete, single feeding pulmonary artery ↪.* **(Right)** *Axial CTA of the same patient demonstrates the feeding artery ↪ and draining vein → of the right lower lobe PAVM. This noninvasive preprocedural CT allows assessment of feeding vessel caliber and location. Careful planning for the intervention ultimately results in decreased procedural time, contrast, and radiation exposure.*

PAVM: Procedural Angiogram



PAVM: Postembolization



(Left) *Selective DSA in the same patient demonstrates the right lower lobe PAVM → once the feeding pulmonary artery branch is selected ↷. There is excellent correlation with the preprocedure CTA used for planning.* **(Right)** *Embolization coils ⇨ were used to occlude the feeding artery of the PAVM. The sheath and catheter are positioned within the feeding artery →.*

INTRODUCTION

Preprocedure Imaging Options

- Preprocedure imaging should be obtained prior to many vascular or nonvascular interventions
    - Mapping of normal/abnormal anatomy/physiology
    - Used for procedure/intervention planning
    - Determination of optimal device size & configuration
- Wide spectrum of imaging options available
    - **Ultrasound**
        - Includes grayscale & color Doppler
    - **Intravascular ultrasound**
        - Typically used concurrently with angiography
    - **Echocardiography**
        - Includes transthoracic echo or transesophageal echo
    - **CT**
        - Includes nongated/gated CTA/CTV
    - **MR**
        - Includes MRA/MRV
    - **DSA**
        - Includes C-arm-based cone beam CT
    - **Radionuclide scintigraphy**
        - Includes scintigraphy, 3D single-photon emission CT, and PET
- Examples of interventions highly dependent on preprocedure imaging for optimal outcomes
    - Vascular malformations
    - Carotid artery stenting (CAS)
    - Abdominal endovascular aneurysm repair (EVAR)
    - Thoracic endovascular aortic repair (TEVAR)
    - Transarterial chemoembolization (TACE)
    - Radioembolization
    - Endovenous thermal varicose vein ablation (EVTA)
    - Percutaneous transhepatic biliary interventions
    - Transjugular intrahepatic portosystemic shunt (TIPS)
    - Uterine artery embolization (UAE)

IMAGING MODALITIES

Ultrasound

- Advantages
    - No radiation exposure
    - Low cost; readily available
    - Excellent delineation between solid & fluid-filled spaces
    - Real-time imaging
- Disadvantages
    - Acoustic window restrictions
    - Operator dependent
    - Patient body habitus dependent

Intravascular Ultrasound

- Advantages
    - Allows accurate visualization of vascular lumen
    - Accurately depicts intraluminal/mural abnormalities
    - Accurate assessment of intravascular device position
- Disadvantages
    - Invasive compared to conventional US
    - Adds procedural expense
    - Adds additional procedural time

Echocardiography

- Transthoracic or transesophageal options
    - Transesophageal requires sedation; invasive
- Advantages
    - Allows flow velocity quantification/gradient calculations
    - No radiation or contrast agents needed
- Disadvantages
    - Acoustic window restrictions
        - Various available acoustic windows: Intercostal spaces, liver, epigastrium, or suprasternal notch
        - Cannot evaluate entire aortic arch/great vessels
        - Limited 3D capability compared to MR/CT

CT

- Advantages
    - Accurately demonstrates vascular anatomy
    - Has excellent 3D spatial resolution
    - Allows post hoc image reconstructions in any plane
    - Best test for imaging of calcium
- Disadvantages
    - Requires iodinated contrast to evaluate vasculature
    - Uses ionizing radiation
    - Ascending aorta pulsation artifacts/pseudoflaps
- Contraindications
    - Severe allergy to iodinated contrast
    - Renal insufficiency
        - Estimated glomerular filtration rate (eGFR) > 60: No contraindication to contrast administration
        - eGFR > 30 & < 60: May proceed with precautions/hydration

MR

- Advantages
    - Phase-contrast imaging allows flow quantification
    - Allows cardiovascular evaluation without IV contrast
    - Best tool for tissue characterization
        - Soft tissue contrast resolution superior to CT
    - May use despite iodinated contrast allergy
- Disadvantages
    - Long procedure; often requires several breath holds
    - High cost; not readily available
    - Inferior spatial resolution
    - Artifacts may mimic disease
    - Does not evaluate calcium well
    - Poor access to patient during examination
        - Difficult life support/monitoring in severely ill
    - Motion sensitive due to long acquisition times
        - May require sedation
- Contraindications
    - Severe claustrophobia
    - Medical implants (e.g., pacemakers, programmable ventricular shunts, medication pumps, brain aneurysm clips)
    - Cannot use gadolinium contrast if renal failure
        - Risk of nephrogenic systemic fibrosis

DSA

- Advantages
    - Guidance for performing vascular interventions
    - Real-time information regarding hemodynamics

- Disadvantages
  - Invasive
    - If sole planning modality, may require staged procedure
  - Ionizing radiation
    - Exposure to patient & procedural personnel
  - Requires administration of intravascular contrast
    - Iodinated contrast typically used
    - May also use CO_2
    - Potential for contrast allergy/anaphylaxis or contrast-induced nephropathy
  - Underestimates vascular calcifications/mural thrombus
  - Can have significant image quality issues due to misregistration artifacts (e.g., motion from patient, bowel, respirations)

Radionuclide Scintigraphy

- Advantages
  - Provides physiologic information
    - PET images uptake of labeled fluorodeoxyglucose (FDG), a glucose analogue; neoplasms are highly metabolic/rapidly synthesize FDG
    - Technetium (Tc-99m) labeled red blood cell scan detects active gastrointestinal bleeding
- Disadvantages
  - Radioisotope exposure
  - Highly sensitive but may be nonspecific

PLANNING FOR SPECIFIC PROCEDURES

Vascular Malformations

- Cross-sectional (CTA/MRA) or ultrasound mapping of vascular anatomy
  - Delineation of inflow artery(ies) & outflow vein(s)
    - Demonstration of nidus & its communications
  - Determination of hemodynamic characteristics
    - High flow vs. low flow
    - Simple vs. complex

Carotid Artery Stenting

- Stenosis severity determined with various modalities
  - Color Doppler ultrasound with spectral analysis
  - CTA/MRA
    - Includes CTA reformations
    - Maximum intensity projections
    - Stenosis severity calculations
  - Digital subtraction angiography
    - Typically combined with CAS procedure
  - Stent choice often based on preprocedural CTA/MRA measurements & arterial anatomy
    - Various stent designs, configurations, & lengths exist
    - Vessel diameters important for sizing stent appropriately for target vessel
  - Embolic protection device (EPD) choice based on CTA/MRA measurements & arterial anatomy
    - Various types of EPDs
    - Vessel diameters & lengths important for sizing EPD appropriately for target vessel

Abdominal Endovascular Aneurysm Repair

- Endograft choice based on CTA/MRA measurements
  - Endograft diameter based on true aortic short axis
    - Measured immediately below lowest renal artery
    - 10-20% oversizing to ensure good graft apposition
- Proximal landing zone requires ≥ 10-mm long segment of normal aortic diameter
- External iliac artery diameter ≥ 7 mm for access
  - Most device delivery systems ≥ 18 Fr
  - Circumferential/excessive calcification limits access
- Excessive iliac artery tortuosity may complicate access
- Aneurysm neck morphology, angulation, & length are determinants of proximal seal zone suitability
  - Neck angulation > 60° is contraindication
  - Nontapered necks most favorable anatomy
  - Reverse tapered (conical) neck problematic
  - Mural thrombus & excessive calcifications problematic
- Bifurcated endografts require minimal distal aortic diameter (a.k.a. distal neck)
  - Can place aortouniiliac graft in small caliber distal aorta, combined with cross-femoral graft
- Branch vessel patency & location can be determined
  - Relationship of renal arteries to neck is critical
  - Large lumbar arteries & patent inferior mesenteric artery may predispose to type II endoleak
- Abdominal aortic aneurysm (AAA) measurements generally include (but not limited to)
  - **Diameters**: Aneurysm neck; aorta at bifurcation; maximal aneurysm diameter; common iliac, external iliac & common femoral arteries
  - **Length**: Lowest renal artery to aneurysm (neck length); lowest renal artery to aortic bifurcation; lowest renal artery to iliac bifurcation
  - **Angles**: Proximal & distal neck angulation; excessive iliac artery angulation

Endovenous Thermal Varicose Vein Ablation

- Preprocedure duplex US imaging
  - Mapping of venous anatomy
  - Assessment of valve closure times & venous reflux
  - Evaluation for incompetent perforators
  - Evidence of postthrombotic obstruction
  - Evaluation for deep & superficial venous thrombosis
- Cross-sectional imaging: CTV/MRV
  - Suspected pelvic/abdominal venous outflow disease
  - EVTA ineffective if venous outflow compromise

Transhepatic Biliary Interventions

- Preprocedure duplex US imaging
  - Demonstrates biliary ductal anatomy
- Cross-sectional CT/MR imaging
  - Demonstrates etiology of biliary obstruction
  - MR cholangiopancreatography useful for preprocedure biliary anatomy
- Hepatobiliary scintigraphy
  - Assessment for biliary leak

Radioembolization

- Targeted treatment for nonoperable primary & secondary hepatic malignancies
  - Preprocedure CECT or contrast-enhanced MR evaluation of tumor burden
    - Used to calculate dose of radioactivity to be delivered
  - CTA/MRA evaluation of vascular anatomy

    - Evaluate for variant anatomy
    - Hepaticoenteric arterial communications
  - Prophylactic embolization of hepaticoenteric arterial communications
    - Elimination of potential pathways for nontarget embolization of injected radioactive spheres
  - Injection of Tc-99m macroaggregated albumin via catheter placed in intended position for radioembolization
    - Followed by radionuclide lung perfusion scan; evaluates lung shunt fraction

Thoracic Endovascular Aortic Repair

- Used for treatment of aneurysm, transection, type B dissection, intramural hematoma, penetrating ulcer
  - Requires satisfactory proximal seal zone
  - May require endograft coverage of left subclavian artery to achieve adequate proximal seal zone
    - Requires vertebral & carotid duplex US; assess if left common carotid to left subclavian artery bypass or left subclavian transposition needed
  - May require debranching of aortic arch to achieve adequate proximal seal zone
  - Requires satisfactory distal landing zone
    - Need 20-mm distal seal zone
  - Endograft choice based on CTA/MRA measurements
    - Endograft diameter based on true aortic short axis
      - Determination of aortic diameter at proximal & distal seal zones of endograft
    - Determination of length of coverage required
    - Assessment of aortic angulation & tortuosity
    - Mural/luminal characteristics of aorta (e.g., thrombus burden, calcifications)
    - Characterization of access vessels
      - Common femoral/iliac artery diameters/tortuosity/calcifications

Transcatheter Arterial Chemoembolization

- Targeted treatment for inoperable primary & secondary hepatic malignancies
  - Preprocedure CECT or contrast-enhanced MR evaluation of tumor burden
    - Need liver parenchyma involvement of < 50%
    - Assess degree of tumor enhancement
      - Hypervascular tumors have better response
  - CTA/MRA evaluation of vascular anatomy
    - Determine arterial supply to tumor(s)
    - Evaluate for variant anatomy
    - Evaluation of portal vein patency

TIPS Creation

- Percutaneously created connection within liver between portal & systemic circulations
  - Preprocedure ultrasound
    - Ultrasound confirmation of portal vein patency
    - Color Doppler US evaluates direction of portal flow (e.g., hepatopetal vs. hepatofugal flow)
    - Presence/absence of ascites
  - Cross-sectional imaging: CT or MR
    - Confirms portal vein patency
    - Evaluates for competing portosystemic shunts
    - Demonstrates location & extent of varices
    - Shows portal & hepatic vein anatomic relationship
      - Allows optimal hepatic to portal vein intraprocedural puncture trajectory
    - Evaluates for extrahepatic portal bifurcation
      - Risk of intraperitoneal hemorrhage if extrahepatic portal vein puncture

Uterine Artery Embolization

- Transcatheter delivery of particles to embolize uterine artery
  - Preprocedure contrast-enhanced MR evaluation of female pelvis
    - Location of fibroids: Submucosal, subserosal, pedunculated, etc.
    - Fibroid size; compression of adjacent structures
    - Vascularity of fibroid; predictive of UAE response
    - Adenomyosis: Junctional zone > 12 mm
  - Pelvic ultrasound
    - Assessment of fibroids: Location, vascularity, size
    - Doppler of uterine cavity (postpartum hemorrhage)
  - CT if claustrophobic patient or MR contraindication
  - Digital subtraction angiography
    - Performed concurrently with embolization
    - Ovarian artery contribution to fibroids
    - Evaluation of utero-ovarian anastomoses

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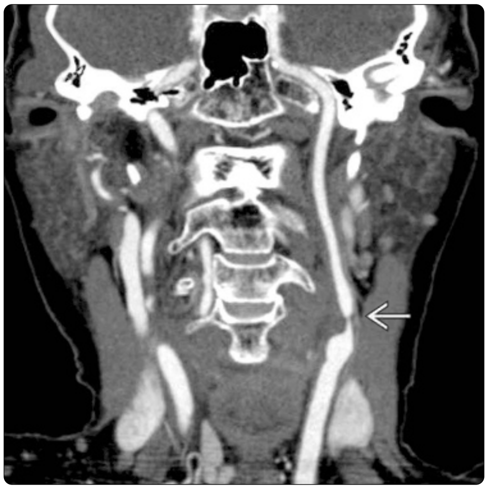
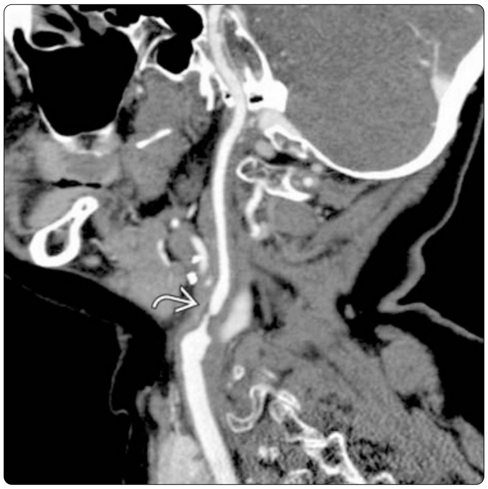
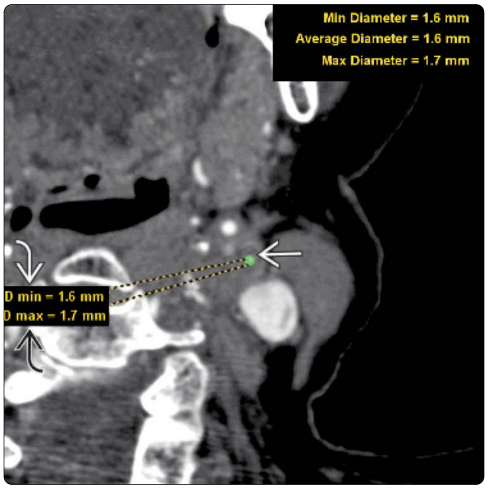
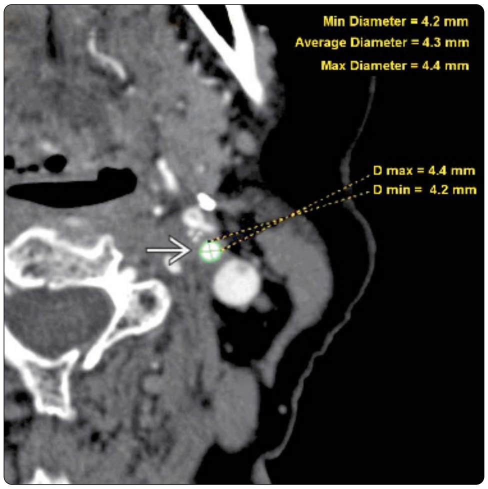
(Left) *Cross-sectional imaging and multiple reformations are important in preprocedure planning for carotid artery stenting. This coronal maximum intensity projection (MIP) shows a severe stenosis ➡ of the left internal carotid artery (ICA) with normal caliber of the ICA distally and the common carotid artery proximally.* **(Right)** *Sagittal MIP confirms the severe stenosis ➦ and a normal-caliber distal left ICA. The arterial caliber impacts the types and sizes of stent and embolic protection devices chosen.*


Carotid Artery Stent: Preprocedural Planning (Coronal MIP from CTA)

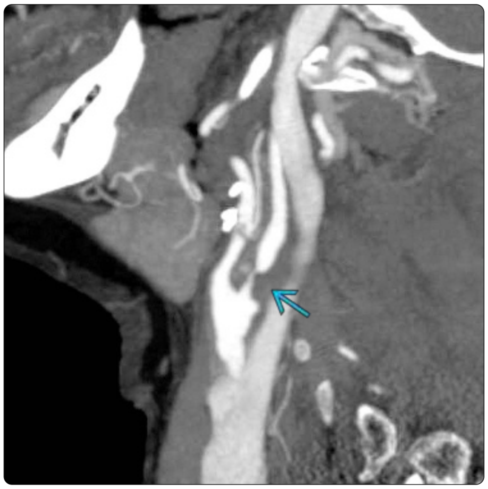

Carotid Artery Stent: Preprocedural Planning (Sagittal MIP from CTA)

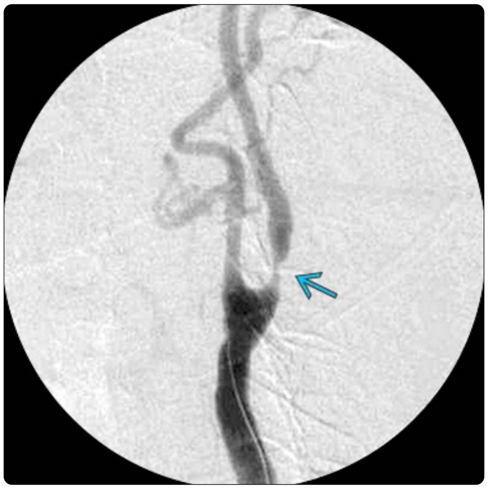
(Left) *Points can be plotted on the reformatted images from the same CTA using postprocessing software on a dedicated workstation. Calculations of the minimum ➦ and maximum ⇗ diameters along the arterial course are made. The degree of stenosis ➡ is evaluated on this image.* **(Right)** *Precise measurements of arterial diameter are important for stent sizing. The normal distal ICA diameter impacts sizing of an embolic protection device, if used. The ICA diameter ➡ at the distal end of the stenosis is calculated here.*


Carotid Artery Stent: Preprocedural Planning (Calculation of Stenosis Severity)

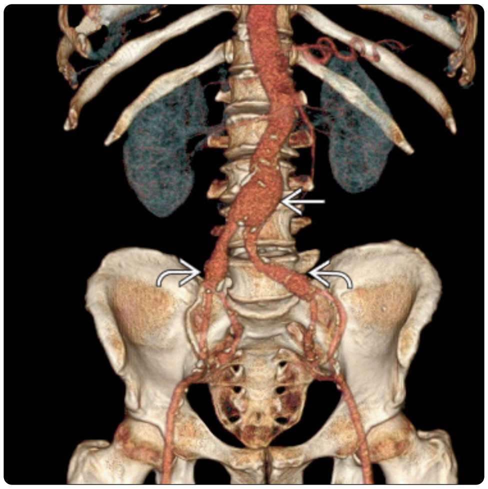

Carotid Artery Stent: Preprocedural Planning (Distal Internal Carotid Diameter)

(Left) *The patient was being evaluated for possible carotid artery stenting because of a history of prior carotid endarterectomy and new onset of slurred speech. The CTA shows a severe left ICA stenosis ⇨.* **(Right)** *An intraoperative DSA correlates well with the preprocedural CTA and confirms the severe ICA stenosis ⇨. The CTA results indicated that the patient was anatomically suitable for carotid stenting with embolic protection.*

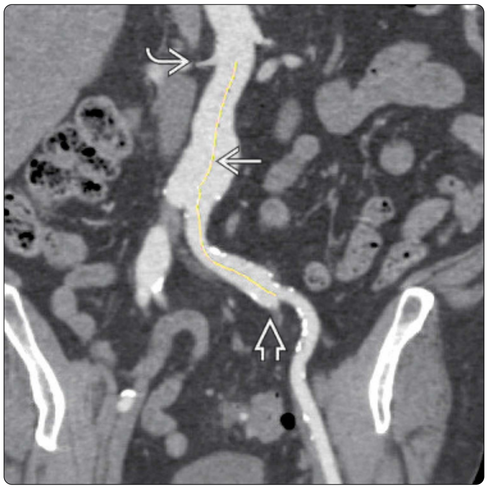

Carotid Artery Stent: Preprocedural and Intraprocedural Comparison


Carotid Artery Stent: Preprocedural and Intraprocedural Comparison

EVAR: Preprocedure Planning (Initial CTA Imaging Evaluation)

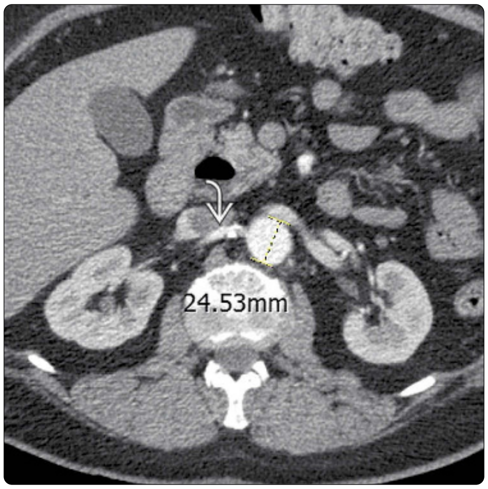


EVAR: Preprocedure Planning (Initial CTA Imaging Evaluation)

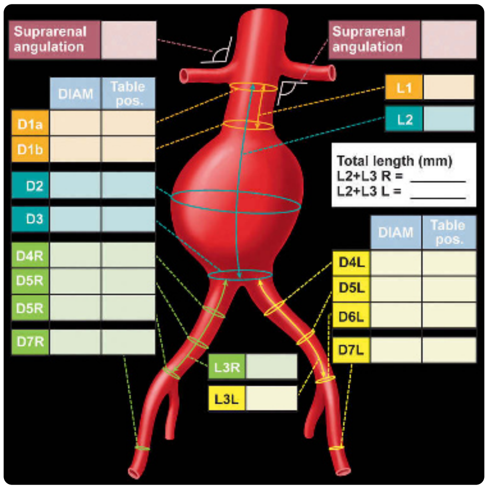


(Left) *3D reformation shows a satisfactory infrarenal neck length above an AAA ➡. Both distal common iliac arteries ↪ are dilated. Careful preprocedural analysis of aortoiliac anatomy is critical to choosing an appropriate endograft for EVAR.* **(Right)** *A centerline ➡ has been plotted on the coronal MIP in the aortic and left common iliac artery lumina from the lowest renal artery ↪ to the iliac bifurcation ⇨. This is used to calculate endograft length and is usually more accurate than using axial table positions.*

EVAR: Preprocedure Planning (Proximal Neck Diameter Calculation)

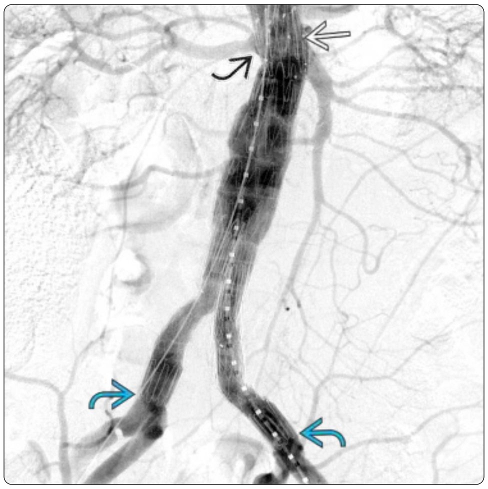


EVAR: Preprocedure Planning (Endograft Sizing Worksheet)

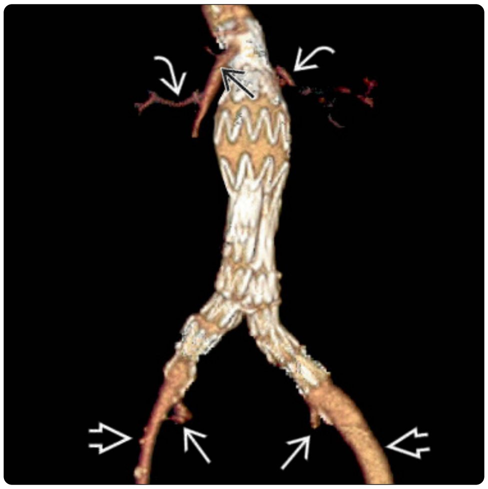


(Left) *Preprocedural axial CECT images are used to calculate diameters at multiple levels. In this image, the aortic neck diameter below the lowest renal artery ↪ is 24.5 mm diameter, evaluated over a 10-15 mm length (the optimal proximal seal zone length). Other important diameters include the aortic bifurcation and the common and external iliac arteries.* **(Right)** *A worksheet is used to plot vessel lengths and diameters from CTA image data. Appropriate endograft size and component lengths are then selected.*

EVAR: Intraoperative DSA Aortogram (Satisfactory Result)

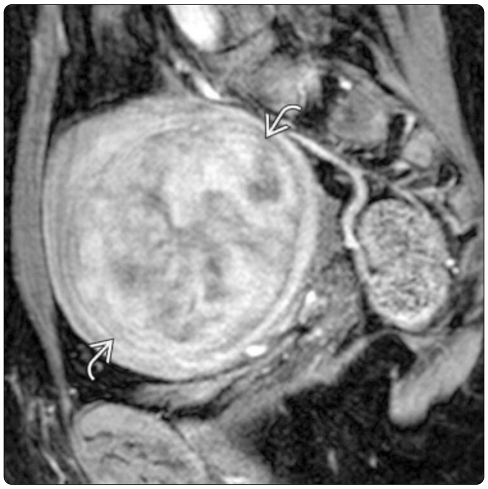


EVAR: Postprocedural Imaging Surveillance (3-Month Follow-Up)

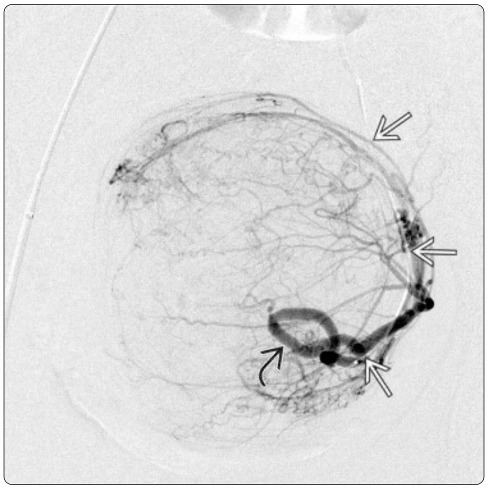


(Left) *DSA during EVAR shows an endograft extending from the lowest renal artery ↪ to both iliac bifurcations ↪. The suprarenal endograft component ➡ consists of bare metal stents designed to aid in proximal fixation. Meticulous preoperative planning is critical to obtaining good EVAR outcomes.* **(Right)** *3D reformatted CTA 3 months after EVAR shows patency of the renal arteries ↪, superior mesenteric artery ➡, and both internal ➡ and external ⇨ iliac arteries. Axial images showed a good endograft position and no endoleak.*

(Left) *Sagittal enhanced T1WI C+ MR in a patient with known uterine fibroids shows a large, heterogeneously enhancing fibroid* ↪*. MR is the preferred modality for preuterine artery embolization evaluation, clearly demonstrating the size and location of fibroids as well as the degree of enhancement.* **(Right)** *Selective left uterine artery* ⇨ *DSA via a coaxial microcatheter* ➡ *shows extensive vascularity, corresponding to the fibroid enhancement seen on MR. Embolization was performed from this catheter position.*

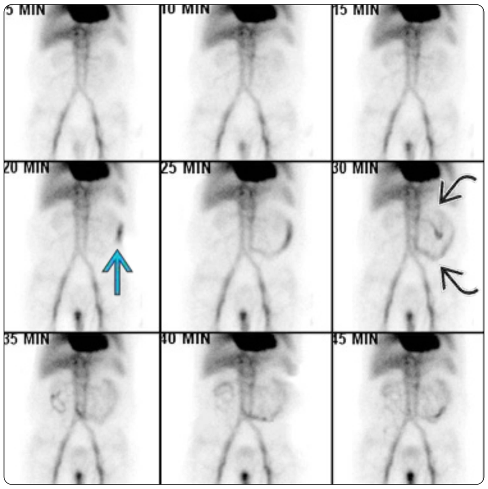


Uterine Artery Embolization: Preprocedural Planning (Sagittal MR)

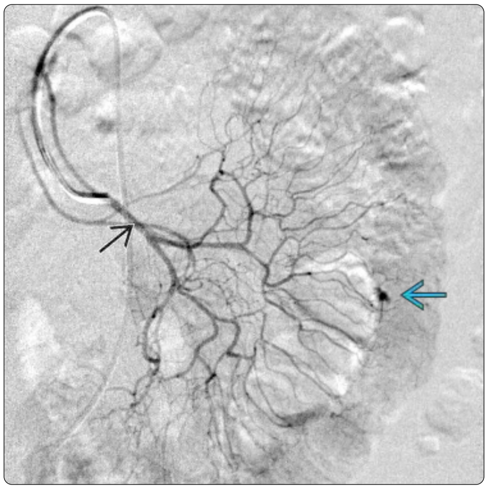


Uterine Artery Embolization: Intraprocedural DSA (Left Uterine Artery)

(Left) *Localizing GI bleeding can be difficult, particularly given its intermittent nature. Tc-99m-labeled red blood cell scintigraphy before DSA can determine if there is active bleeding and its location. Here, activity in the left abdomen* ➡ *accumulates in a small bowel distribution* ↪*.* **(Right)** *As scintigraphy suggested, bleeding* ➡ *localized to a jejunal branch* ➡ *of SMA. Evaluation of celiac and IMA arteries was unnecessary, limiting contrast load and radiation dose during treatment.*

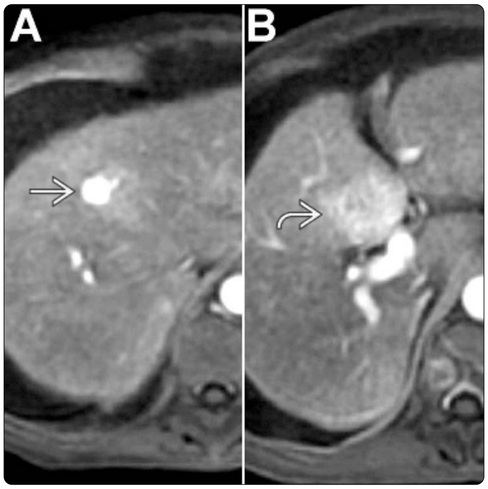


Acute Gastrointestinal Hemorrhage (Tc-99m-Labeled RBC Scintigraphy)

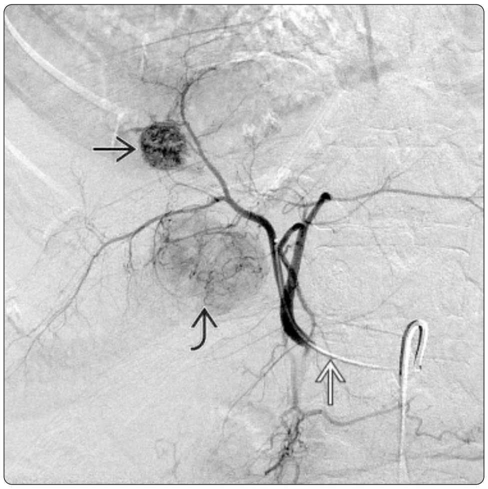


Acute Gastrointestinal Hemorrhage (Digital Subtraction Angiography)

(Left) *(A) MR shows a 1.5-cm enhancing mass* ➡ *in segment VIII and (B) a 3.5-cm enhancing mass* ↪ *in segment V, consistent with hepatocellular carcinoma. Cross-sectional imaging with MR or CT assesses tumor number, location, and vascularity, plus vascular anatomy prior to TACE, and is more sensitive than intraprocedural DSA.* **(Right)** *Preprocedural imaging helps plan TACE as bilateral staged, lobar, or segmental. Here, a selective coaxial microcatheter* ⇨ *confirms masses in segments VIII* ➡ *and V* ↪*.*

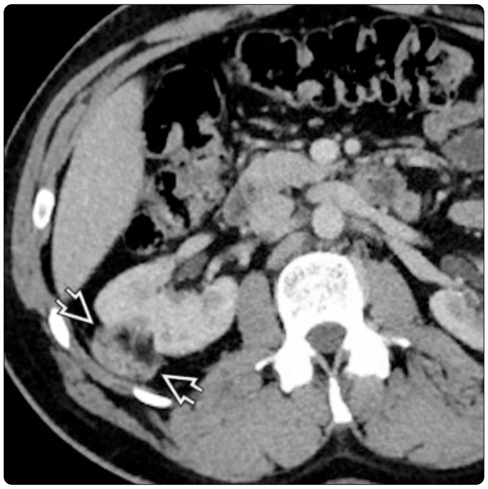


TACE of Hepatocellular Carcinoma: Preprocedural Evaluation (Initial MR)

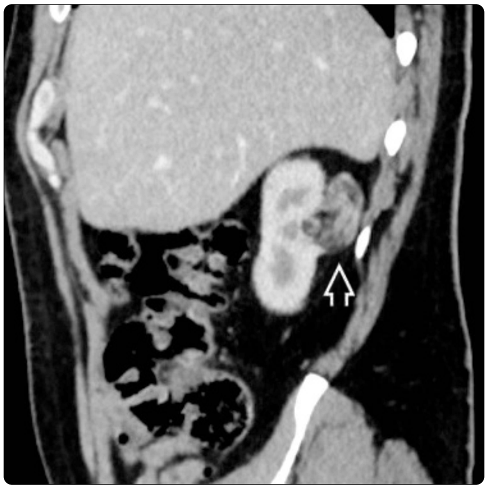


TACE of Hepatocellular Carcinoma: Intraprocedural (Preembolization DSA)

Angiomyolipoma: Preprocedural Planning (Axial CECT)

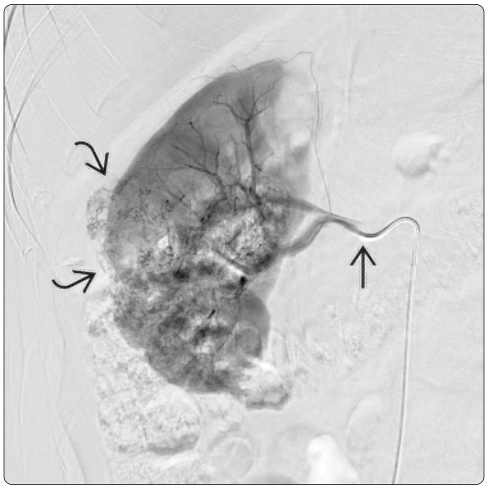


Angiomyolipoma: Preprocedural Planning (Sagittal CECT)

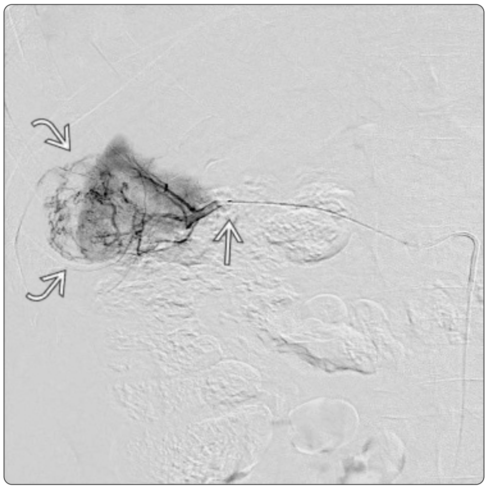


(Left) *Axial CECT demonstrates an exophytic, enhancing, fat-containing mass ➡ involving the right kidney representative of an angiomyolipoma.* **(Right)** *Sagittal CECT confirms the exophytic nature ➡ of the right renal angiomyolipoma. Preprocedural imaging suggests that, due to the location of the mass, a partial nephrectomy may be challenging. Alternatively, no barriers to endovascular embolization are apparent.*

Angiomyolipoma: Procedural Embolization (Renal Arteriogram)

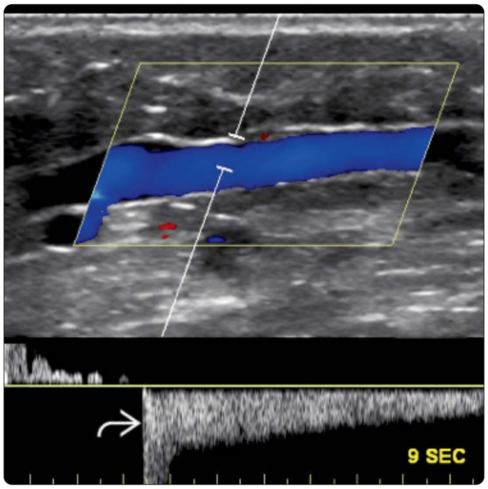


Angiomyolipoma: Procedural Embolization (Superselective Angiogram)

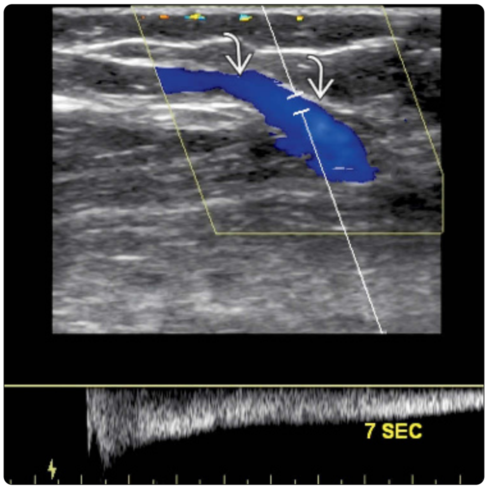


(Left) *A nonselective right renal arteriogram ➔ demonstrates arterial blush ↪ and neovascularity associated with the exophytic angiomyolipoma.* **(Right)** *A coaxial microcatheter was advanced until this superselective right renal arteriogram ➡ demonstrated arterial blush ↪ of the angiomyolipoma, correlating well with the preprocedure CT. Particle embolization from this location treated the angiomyolipoma and minimized injury to uninvolved kidney.*

Endovenous Thermal Ablation (Doppler Evaluation for Reflux)



Endovenous Thermal Ablation (Doppler Evaluation for Reflux)



(Left) *Ultrasound mapping of the deep and superficial veins of the lower extremities and color Doppler evaluation of venous reflux are mandatory prior to thermal ablation of varicose veins. This case demonstrates 9 seconds of reflux ↪ in the left great saphenous vein, indicating the presence of venous insufficiency.* **(Right)** *Color Doppler US shows a large, refluxing superficial varix ↪ located within the posterior thigh. Preprocedure duplex ultrasound should include evaluation for incompetent perforators as well.*

KEY FACTS

PREPROCEDURE WORK-UP

- Review pertinent medical history, imaging, labs, indication for procedure
- Risk stratify for cardiac events, contrast-induced nephropathy, complications of sedation
    - Take appropriate steps (e.g., cardiology consult, pre and postprocedure hydration, anesthesia support)

INFORMED CONSENT

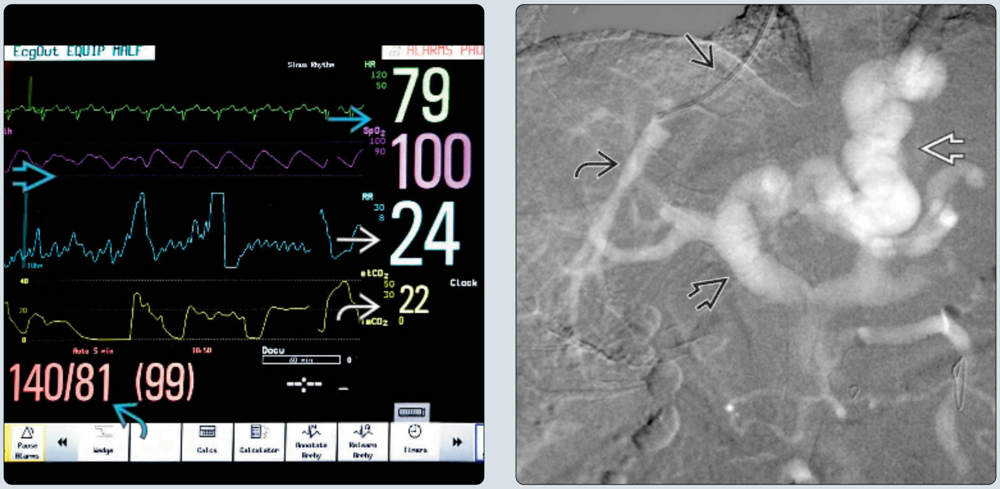
- Communication process between patient/patient's representative to authorize intervention
- Components include nature of procedure (purpose, risks, and benefits), alternatives, patient understanding, and voluntary acceptance
- Exception: Presumed consent in life-/limb-threatening emergency, no surrogate

SEDATION

- Choose desired sedation level based on patient factors, operator preference, patient preference, and procedural complexity
- Moderate sedation most often used
    - Typically combination of benzodiazepine (Versed) and opioid (fentanyl)
    - Opioid reversal with naloxone; benzodiazepine reversal with flumazenil

TIME OUT

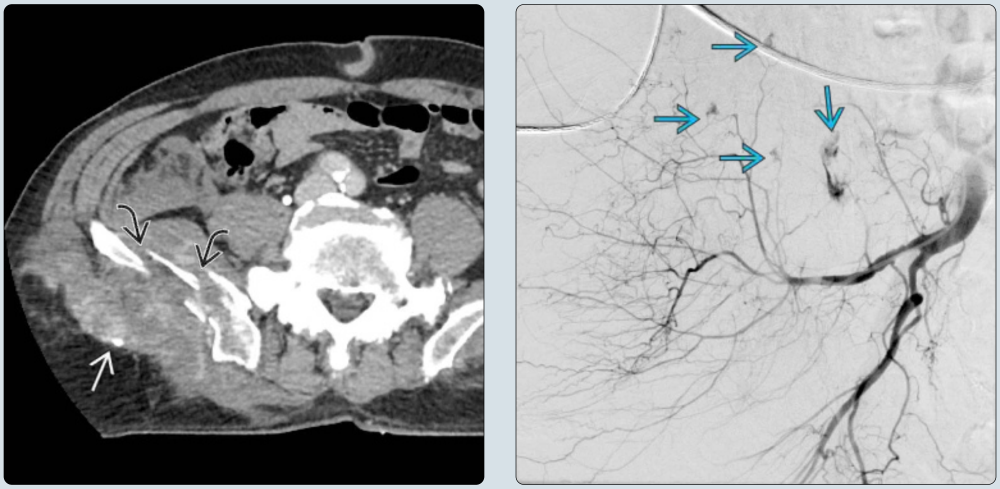
- Ensure right patient, right procedure, correct side/site, signed informed consent
- Review relevant labs, history, need for antibiotics, special equipment



Vital Signs: Continuous Monitoring

Alternative Contrast Agents: CO2

(Left) *Procedure with moderate sedation is shown. Pulse → and oxygen saturation → are continuously monitored. Blood pressure ↪ is taken every 5 minutes. End-tidal CO_2 ↪ and respiratory rate ➡ can also be monitored. This patient was hyperventilating. (Normal $etCO_2$ 35-45, RR < 20.)* **(Right)** *CO_2 contrast is an alternative for patients unable to receive iodinated contrast. Here, CO_2 injection via a catheter → in the hepatic vein ↪ opacifies the portal vein ⇨ and esophageal varices ⇨ during TIPS.*



Pre-Procedural Planning & Imaging

Procedural Angiogram: Correlates with CT

(Left) *Axial CECT shows a patient who sustained significant trauma after being stuck by a car. Insignificant comminuted pelvic fractures are present ↪ as is evidence of contrast extravasation ➡. Patient had concomitant head injuries and was intubated. No next of kin was available. Presumed consent was invoked to proceed with pelvic angiogram and embolization.* **(Right)** *A right internal iliac angiogram shows multifocal areas of extravasation →. These were treated with gelfoam embolization. Patient was ASA class V-E*

PREPROCEDURE WORK-UP

Cardiac Risk Stratification

- Revised Cardiac Risk Index
    - Point given for each of the following
        - High-risk procedure
        - Ischemic heart disease
            - History of myocardial infarction, angina, abnormal stress test, pathologic Q waves
        - Congestive heart failure
        - History of cerebrovascular disease
        - Insulin-dependent diabetes
        - CKD with GFR > 2 mg/dL
    - Cardiac adverse event rate
        - 0 points: 0.4%
        - 1 point: 1%
        - 2 points: 7%
        - ≥ 3 points: 11%

Contrast-Induced Nephropathy Risk Stratification

- Definition: Increase in serum creatinine by 25% from baseline within 72 hours of contrast administration
- Natural course
    - Typically transient increase in serum creatinine
        - Peaks at 4-7 days
    - < 1% will progress to ESRD/need dialysis
- Scoring system
    - Hypotension or intraaortic balloon pump use = 5 points
    - Congestive heart failure = 5 points
    - Elevated baseline kidney function (serum creatinine > 1.5 mg/dL) = 4 points
    - > 75 years of age = 4 points
    - Anemia = 3 points
    - Diabetes mellitus = 3 points
    - Contrast volume = 1 point for each 100 mL used
- Prevention
    - Hydration
        - Elective outpatient: Oral hydration 12-24 hours before and after procedure
        - Elective inpatient: 1 mL/kg/h x 12 hours before and 12 hours after contrast administration

Preprocedure Performance Status

- Correlated with overall patient prognosis and postprocedure outcome
- Eastern Cooperative Oncology Group (ECOG) commonly used scales for cancer patients
    - Score between 0 (fully active) and 5 (dead)
- Commonly used scales for patients with liver disease
    - Model For End-Stage Liver Disease (MELD) score
        - MELD = 3.78×ln[serum bilirubin (mg/dL)] + 6.43 + 11.2×ln[INR] + 9.57×ln[serum creatinine (mg/dL)]
        - Originally used to predict outcome after TIPS
        - Prognostic indicator in chronic liver disease
        - 3-month mortality
            - > 40 ~ 70% mortality
            - 30-39 ~ 50% mortality
            - 20-29 ~ 20% mortality
            - 10-19 ~ 5.0% mortality
            - < 9 ~ 2% mortality
        - Also applied as objective tool in assigning need for liver transplant
    - Child-Pugh score
        - Based on grade of hepatic encephalopathy, severity of ascites and values of INR, albumin, and total bilirubin
        - Predictive of 1-year survival
            - A: 100%; B: !00%; C: 45%
        - Incorporated in triage of treatment for patients with HCC in Barcelona Clinic Liver Cancer (BCLC) staging

SEDATION

Level of Sedation

- Base sedation plan on procedural complexity & patient
- Sedation levels (in order of decreasing sedation)
    - General endotracheal anesthesia
    - Monitored anesthesia care
    - Deep sedation
    - Moderate sedation
    - Minimal sedation/anxiolysis
    - Local anesthesia only

Moderate Sedation

- Most often employed sedation plan/level for routine IR procedures
- Definition: Sedation state allowing patient to retain ability to respond purposefully to verbal/tactile stimuli
    - Cardiovascular function, respiratory function, and airway maintained
- Typical agents: Benzodiazepine (e.g., midazolam) + opioid (e.g., fentanyl)
    - Act synergistically
- Benzodiazepine
    - Actions: Anxiolysis, antegrade amnesia, sedative, muscle relaxation
    - Enhances effect of gamma-aminobutyric acid (GABA)
        - Reduces neuronal excitability
- Midazolam (a.k.a. Versed) preferred benzodiazepine
    - Typical adult midazolam dose
        - 0.5-2 mg initial bolus
        - 0.5-1 mg additional doses as needed
        - Use lower doses in debilitated patients, elderly patients, patients with respiratory insufficiency, hepatic impairment, renal failure
            - Single dose: Metabolism unchanged with renal failure
            - Multiple doses: Prolonged procedure increases duration of effect due to byproduct accumulation
            - Hepatic impairment → decreased clearance with stronger and prolonged effects
    - Pharmacokinetics
        - Metabolized by liver, excreted in urine
        - Onset of action: 2-5 minutes after IV injection
            - Wait 5 minutes before redosing
        - Elimination half life: 1.5-2.5 hours
            - Prolonged in elderly, obese, chronically ill, patients with CHF, patients with liver impairment, patients with renal impairment
        - Obesity: Systemic clearance of midazolam unchanged
    - Paradoxical reaction

    - Agitation, involuntary movements, hyperactivity, hostility, excitement
      - Seen in children, elderly, patients with dementia
  - Pregnancy class D
    - Excreted in breast milk
  - Reverse with flumazenil
    - Dose: 0.2 mg
      - Repeat q 45 seconds; can repeat 3x
    - Action: Competitive inhibition at benzodiazepine binding site on GABAA receptor
    - Biological half life: 15-30 minutes
      - Redosing may be necessary to avoid resedation
    - Lowers seizure threshold, may cause agitation
- Opioid
  - Action: Analgesia
    - μ opioid receptor agonist
  - Side effects/adverse reactions
    - Confusion, somnolence, constipation, nausea, hypoventilation/apnea, chest wall rigidity (especially in pediatric patients), bradycardia, itching, nausea
- Fentanyl (a.k.a. Sublimaze) preferred opioid
- Typical adult fentanyl dose
  - 25-50 μg initial bolus
  - 25-50 μg additional doses as needed
    - Highly potent (50-100x stronger than morphine)
    - Wide therapeutic index
- Pharmacokinetics
  - Onset: Immediate to 5 minutes
  - Biological half life: 10-20 minutes
  - Metabolized in liver
    - Hydrolysis of esters
    - Cirrhosis/hepatic failure does not affect pharmacokinetics
    - Decreased hepatic blood flow affects metabolism more than hepatic failure/cirrhosis
  - Excreted in urine and feces: No active metabolites, no need for dose reduction in renal failure
  - Lipophilic: Increased volume of distribution in obese patients with prolonged effects
- Pregnancy class C
  - Does enter breast milk
- Naloxone duration < fentanyl; monitor for resedation
- Opioid antagonist: Naloxone 0.4 mg q 4 minutes
- Presedation checklist
  - Allergies, medications, cardiovascular issues
    - Ejection fraction (EF) < 30%: Consider anesthesiology

Presedation Checklist

- NPO status (institution specific)
- Risk factors for potential adverse events
  - Mallampati Score 3 or 4
    - Class 1: Soft palate and uvula completely visible
    - Class 2: Uvula completely visible
    - Class 3: Only base of uvula visible
    - Class 4: No part of uvula visible
  - Facial dysmorphism (micrognathia), facial trauma, obesity
  - Hx of continuous positive airway pressure (CPAP) dependent sleep apnea
  - Problems with prior sedation
  - EF < 30%
  - ASA score IV or V
- 0.5% adverse cardiopulmonary events from moderate sedation
  - Proper patient selection and early recognition and appropriate intervention avoids complications

IODINATED CONTRAST REACTIONS

Prophylaxis Regimens

- For patients with history of mild/moderate reactions
  - Aim to prevent progression to severe reactions
  - May still have mild reactions
- 13-hour prep (preferred)
  - Prednisone 50 mg PO at 13, 7, & 1 hours prior and diphenhydramine 50 mg (PO/IV/IM) 1 hour prior to contrast administration
- 1-hour prep (for emergencies)
  - Methylprednisolone 40 mg IV and diphenhydramine 50 mg (PO/IV/IM) 1 hour prior to contrast administration

Treatment of Reactions

- Hives
  - PO/IV diphenhydramine 25-50 mg ± IM epinephrine (1:1,000) 0.1-0.3 mg
- Facial/laryngeal edema
  - O_2 6-10 L/min (via facemask)
  - IM epinephrine (1:1,000) 0.1-0.3 mg
  - If significant, call code blue for anesthesia back-up and possible intubation
- Bronchospasm
  - O_2 6-10 L/min (via facemask)
  - IM epinephrine (1:1,000) 0.1-0.3 mg
  - Albuterol nebulizer
  - If falling O_2 saturation, increased work of breathing or lack of response to tx, call code blue
- Hypotension with tachycardia
  - Elevate legs
  - Bolus 500-1,000 mL normal saline
  - O_2 6-10 L/min (via facemask)
  - Consider IM epinephrine (1:1,000) 0.1-0.3 mg
    - Alternatively IV epinephrine (1:10,000) 0.1 mg
- Hypotension with bradycardia
  - Elevate legs
  - Bolus 500-1,000 mL normal saline
  - O_2 6-10 L/min (via facemask)
  - IV atropine 0.6-1 mg

CO_2 Contrast

- Advantages: Not allergenic, not nephrotoxic, inexpensive, may use unlimited amounts
  - Wait 2 minutes between injections to allow for expulsion by lungs
- Disadvantages
  - Cannot be used above diaphragm
    - Risk of gas embolism to cerebral, coronary arteries and spinal cord
  - Vessel size underestimation
    - Dependent part of vessel not opacified
      - Posterior plaques/stenoses/pathology not depicted
  - Worser image quality

American Society of Anesthesiologists (ASA) Physical Status Classification System

Score	Description
ASA I	Normal, healthy patient
ASA II	Mild systemic disease (e.g., obesity with BMI 30-40, current smoker, well-controlled DM or HTN)
ASA III	Severe systemic disease (e.g., obesity with BMI > 40, ESRD on hemodialysis, alcohol dependence, poorly controlled DM or HTN)
ASA IV	Severe illness that is constant threat to life (e.g., recent stroke or MI, sepsis, severe reduction in ejection fraction)
ASA V	Moribund patient; not expected to survive without operation (e.g., ruptured AAA, massive trauma)
ASA VI	Brain-dead patient; organs being harvested

Addition of "E" denotes an emergency surgery; delay would cause increase in morbidity or mortality.

Aldrete Score

Activity	Respiration	Consciousness	Circulation	Color	Score
Moves all extremities voluntarily or on command	Breaths deeply, normally and coughs freely	Fully awake, alert	Blood pressure at or within 20% of preprocedure value	Normal	2
Moves 2 extremities voluntarily or on command	Dyspnea or shallow breathing	Arousable to voice	Blood pressure 20-50% of preprocedure value	Pale	1
Does not move	Apneic	Not responsive to voice or touch	Blood pressure > 50% different than preprocedure value	Cyanotic	0

Score for the measurement of recovery after anesthesia (post anesthesia), which includes activity, respiration, consciousness, blood circulation and color. Score ≥ 9 typically required prior to discharge.

Ead H: From Aldrete to PADSS: Reviewing discharge criteria after ambulatory surgery. J Perianesth Nurs. 21(4):259-67, 2006.

-
    - Higher radiation used as faster filming rates needed
- Contraindications: Pulmonary hypertension, COPD, right-to-left shunt
- Complications
    - Vapor lock in heart
        - Trapping of CO_2 in right atrium preventing normal venous return
            - ◻ Causes bradycardia and hypotension
            - ◻ Occurs exclusively during venography
            - ◻ May reflect contamination with room air
        - Place patient into left lateral decubitus position
    - Vapor lock in mesenteric arteries
        - Can cause abdominal pain
        - More common in patients with AAA

MONITORING

Intraprocedural Monitoring

- Continuous oxygen saturation monitor
    - Pulse oximetry: Measures O_2 saturation in blood
        - Slow to indicate change in ventilation
            - ◻ Takes 1-2 minutes to show change
- Continuous ECG
    - Arrhythmia could signify malpositioned guidewire/catheter
- Blood pressure (q 5 minutes)
    - Hypotension and desaturation
        - DDx: Oversedation, pneumothorax
    - Hypotension and tachycardia
        - DDx: Active bleeding, infection
- Capnography: Carbon dioxide monitoring
    - Hypoventilation/hypercarbia precedes desaturation
        - Capnography: Noninvasive measurement of partial pressure of carbon dioxide in exhaled breath
            - ◻ Measure of ventilation
            - ◻ Provides rapid evaluation of patient condition
    - Normal $EtCO_2$ 35-45 mm Hg
        - > 45 = hypoventilation (oversedation)
        - < 35 = hyperventilation (anxiety/pain)

Postprocedure Monitoring/Discharge

- Recovery length and appropriateness of discharge depends on patient, procedure, procedure length, complications, dose of sedation and institution
    - Typical criteria
        - Modified Aldrete score of ≥ 9 or return to patient's baseline
        - Patient not suffering from nausea, vomiting, or significant pain
        - Patient accompanied by responsible adult
    - If reversal agent given, watch for resedation for 1.5 hours after reversal agent given
- No driving, operating heavy machinery, important decisions x 24 hours after sedation
- Amnesia can persist for hours after sedation; give written postprocedure instructions

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1. Rafiei P et al: Society of Interventional Radiology IR Pre-Procedure Patient Safety Checklist by the Safety and Health Committee. J Vasc Interv Radiol. 27(5):695-9, 2016

KEY FACTS

TERMINOLOGY

- Radiation risk is inversely related to patient age
- Sequela of radiation exposure is often delayed

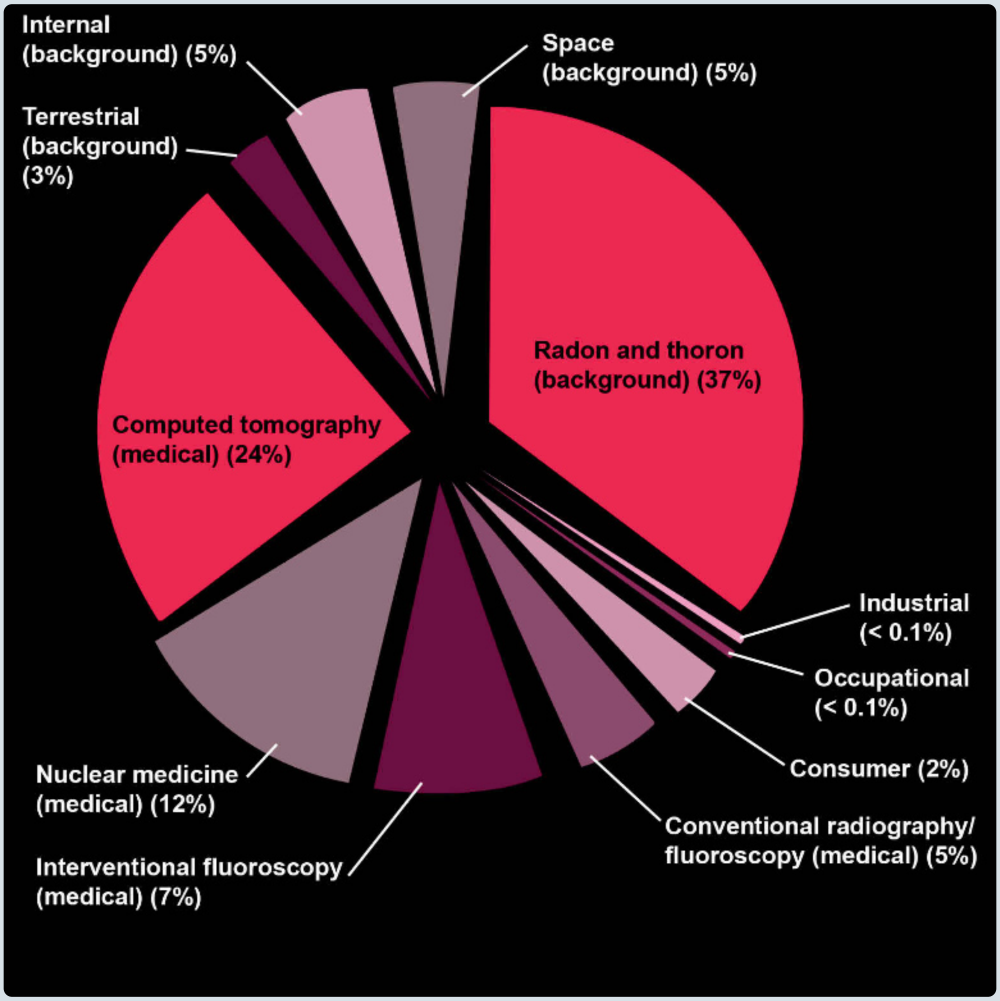
PREPROCEDURE

- Evaluate imaging to determine if procedure requires ionizing radiation
    - If ionizing radiation required, evaluate how to minimize dose
        - Dose reduction should not be done at sacrifice of procedural safety or efficacy
        - CT-guided procedures often do not require same image quality as diagnostic CT studies
    - Check if patient has already received significant radiation to procedural area
        - Repeated smaller, fractionated doses can also cause radiation injury

POST PROCEDURE

- Discuss with patient if exam required significant radiation dose (any of following)
    - Peak skin dose > 3 gray (Gy)
    - Reference point air kerma > 5 Gy
    - Kerma air product > 500 Gy·cm^2
    - Fluoroscopy time > 60 minutes
- Advise patient on possible side effects
    - Explain that symptoms may not appear for weeks to months
- Plan appropriate follow-up

All Exposure Categories: Percentage of Collective Effective Dose (2006)



The largest source of collective effective dose to USA population as of 2006 was from radon and thoron background radiation at 37%. The largest contribution to medical radiation exposure was computed tomography at 24%, followed by nuclear medicine at 12%. Interventional fluoroscopy comprised 7% of total effective dose.

TERMINOLOGY

Definitions

- **As low as reasonably achievable (ALARA)**: Effort to maintain exposures to radiation as far below dose limits as is practical

Radiation Basics

- **Absorbed dose**: Amount of energy absorbed by matter
    - Measured in **gray (Gy)**, a Standard International (SI) unit
    - 1 Gy = 1 joule/kg
    - Radiation-absorbed dose (rad); outdated unit
        - 0.01 Gy = 1 rad
- **Equivalent dose**: Radiation dose weighting based on harmful biologic effect of dose
    - Measured in **sieverts (Sv)**, an SI unit
    - 1 Sv = 100 roentgen equivalent man **(rem)**, a non-SI unit
        - 1 rem increases chance of cancer by 0.055% over lifetime
        - Millirem (mrem): Often used to describe medical device dosage
- **Effective dose**: Equivalent dose accounting for tissue/organ sensitivity and specific damage from radiation
    - Measured in Sv (SI) or rem (non-SI)
- **Effects of ionizing radiation**
    - **Deterministic**
        - Effects exhibit threshold; below threshold, effect is not observed
        - Severity of effect increases with increasing dose above threshold (e.g., radiation-induced hair loss, skin injury, cataracts, sterility)
    - **Stochastic**
        - Probabilistic; nondeterministic health effects
        - Probability of event increases linearly with increasing dose without threshold, but severity of effect is constant (e.g., cancer)
    - **Biologic effect of radiation doses**
        - 10 Sv: High probability of death within days/weeks
        - 1 Sv: 5.5% ↑ probability of cancer during lifetime
        - 100 millisieverts (mSv): 0.5% probability of cancer during lifetime
        - Radiation risk is inversely related to patient age
        - Sequela of radiation exposure is often delayed, frequently weeks to months after exposure

PREPROCEDURE

Preprocedure Imaging

- Evaluate imaging to determine if procedure requires ionizing radiation
- If ionizing radiation required, evaluate best strategies and patient position to reduce dose

Getting Started

- **Factors affecting fluoroscopy dose**
    - Patient size
    - Peak kilovoltage (kVp), milliamps (mA), time
    - Distance from source
    - Image magnification and collimation
    - Beam angle: Perpendicular, oblique, lateral

PROCEDURE

Ways to Reduce Patient Dose in Fluoroscopy

- Optimize available resources
    - Utilize ultrasound guidance when possible/safe
    - Review prior imaging before starting case (limits repeat intraprocedural imaging)
    - Understand patient's prior surgical and medical history prior to starting case (limits unnecessary imaging in certain instances)
- Utilize pulse fluoroscopy
    - Lowest frame rate possible while maintaining procedure safety and efficacy
    - Lower frame rate = lower dose
- Last image hold rather than spot images
- Demagnify: Limit magnification
    - Magnification (geometric and electronic) generally increases dose
- Collimate beam: Limit visualization to area of interest
- Minimize fluoroscopy time
    - Do not fluoro while moving patient or C-arm
- Minimize use of digital subtraction angiography
    - Can use last image hold to document normal findings (e.g., femoral access site, patent hemodialysis access)
- Maximize source to patient difference (i.e., increase patient table height)
    - Dose is exponentially inversely related to distance from source
- Minimize distance from patient to detector
    - Moving detector 4 inches closer to patient = 17-29% dose reduction
- Remove unnecessary tissue within image field
    - Arms out of beam on lateral views
    - Oblique to get spine out of beam if possible
- Place leaded shields under/covering patient outside of area of interest
    - Circumferential shielding for pregnant patients
- Periodically adjust beam angle
    - Reduces dose to specific area of tissue; spreads dose over larger area of tissue

Ways to Reduce Operator Dose in Fluoroscopy

- Reduce patient dose: Reduces scatter to operator
    - Highest dose to proceduralists occurs via scatter
- Wear radiation protection equipment (e.g., leaded glasses, thyroid shield, vest, skirt)
- Maximize distance between operator and patient/source
    - Step out of room for power injections/DSA
    - Use extension tubing for hand injections
    - Optimize location of source, patient, monitors, and equipment to maintain maximum operator distance
        - Some procedures (e.g., hemodialysis access declot, vertebroplasty, left-sided biliary access) require operator to stand quite close, even minimally increased distance achieved can result in significant operator dose reduction
- Radiation shields
    - Ceiling-mounted mobile shield
    - Rolling mobile shields
    - Under-table shields

Annual Occupational Dose Limits

	Standard International (SI) Units	Non-SI Units
Total effective dose (whole body)	50 mSv	5 rem
Lens	150 mSv	15 rem
Skin, organ, extremity	500 mSv	50 rem
Total effective dose (fetus)	5 mSv	0.5 rem

Tissue Reactions to Acute Radiation Exposures

Dose	Expected Reactions
< 2 gray (Gy)	Cataract formation, marrow suppression, cognitive impairment
2 Gy	Transient skin erythema, cataract formation
3 Gy	Temporary hair loss, permanent sterility (testes)
4 Gy	Temporary hair loss
5 Gy	Prolonged skin erythema, partial permanent hair loss
6 Gy	Permanent sterility (ovaries), pneumonitis
7 Gy	Permanent hair loss, renal failure
10 Gy	Prolonged skin erythema, skin atrophy, telangiectasia
15 Gy	Skin necrosis

Note: Many reactions are not acute and may take weeks to months to develop.

- Angle detector toward operator when doing oblique or lateral imaging (i.e., radiation source further from operator)
    - Reduces scatter to operator
    - More patient scatter occurs toward source
- Wear radiation monitoring badges (whole body, ring)
    - Review quarterly dose reports; anticipate results based on work performed, recognize unexpected results
- Exclude hands from fluoroscopy beam
    - Angle fluoroscopy source and detector
    - Intermittently visualize between maneuvers requiring hands within field
    - Collimate tightly when hands near beam
    - Hold procedural equipment in place with hemostats or towels when visualizing

Ways to Reduce Patient Dose in CT

- Reduce kVp
    - kVp of 100 is good initial level
    - May require increase in mA but overall dose decrease
- Increase pitch
- Minimize number of scans
- Minimize field of view
- Limit localizing/scout images

Pregnant Patient Guidelines

- Emergent: Use ionizing radiation if clinically appropriate
- Nonemergent: Optimize ultrasound/MR before CT/fluoroscopy
    - Left flank pain: Consider ultrasound evaluation for hydronephrosis
    - Left lower quadrant pain: Consider ultrasound evaluation for ovarian torsion
    - Right lower quadrant pain
        - < 31 weeks pregnant, consider ultrasound
        - > 31 weeks pregnant, consider MR
- If planned dose > 10 mGy, consider advice of medical physicist
- If delivered dose > 50 mGy, case will likely require review by medical physicist
    - Pulmonary embolism protocol CT can deliver 20 mGy to each breast
        - 2-view mammogram typically delivers 3 mGy

POST PROCEDURE

Expected Outcome

- Risk of appropriate, limited medical imaging
    - Inconclusive epidemiological data
    - Linear no-threshold model currently used may be overly conservative
    - Medical imaging typically performed in older, selective population
- Relative risk of appropriate, limited medical imaging
    - Hard to define since lifetime risk of cancer is relatively high (as high as 42%) even without medical imaging

Things To Do

- Discuss with patient when exam performed required significant radiation dose
    - Advise patient on possible side effects
    - Plan appropriate follow-up

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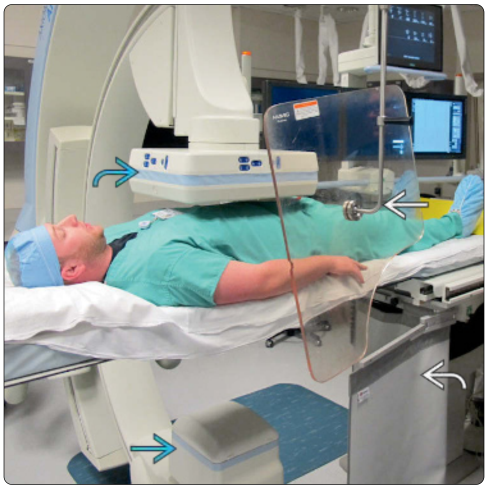
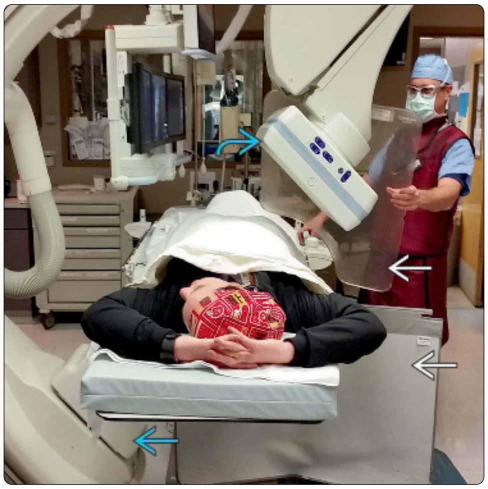
1. United States Nuclear Regulatory Commission. NRC Regulations (10 CFR). Part 20: Standards for protection against radiation. Published June 31, 2015
2. Authors on behalf of ICRP et al: ICRP publication 118: ICRP statement on tissue reactions and early and late effects of radiation in normal tissues and organs--threshold doses for tissue reactions in a radiation protection context. Ann ICRP. 41(1-2):1-322, 2012

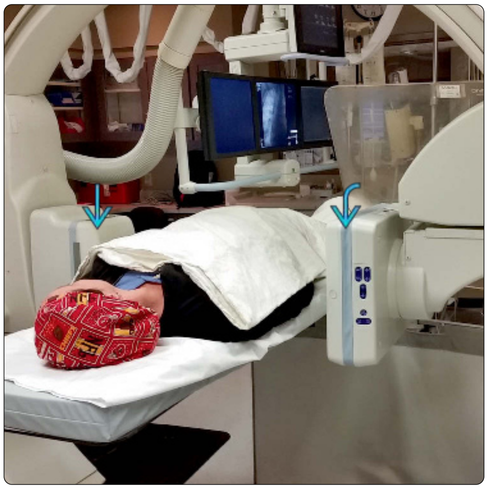


Dose Reduction: Patient and Operator

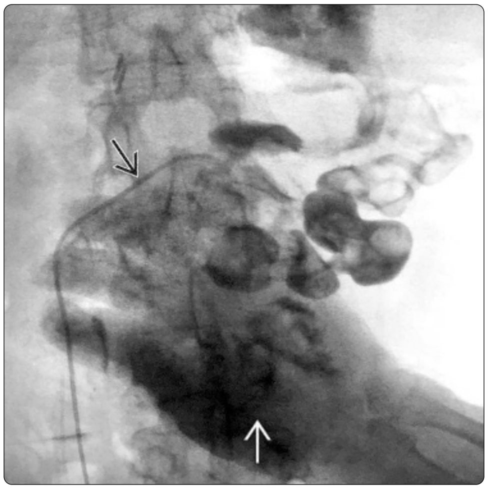


Dose Reduction: Oblique and Lateral

(Left) *The patient is elevated away from the radiation source ⇨, as close to the detector ⤴ as possible. Ceiling-mounted ➡ and table-mounted ➦ mobile shields are in position.* **(Right)** *During oblique or lateral imaging, the radiation source ⇨ should be directed away (and the detector ⤴ toward) the operator if possible, decreasing operator exposure to scatter radiation. Mobile shields ➡ are in use, and the operator has a light-weight protective vest, skirt, thyroid, and eyewear shielding.*

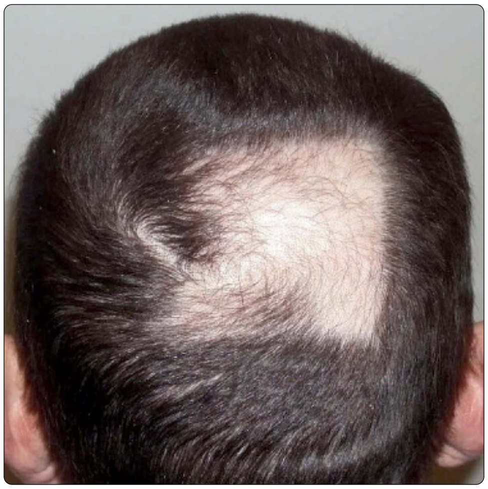


Suboptimal: Lateral Dose

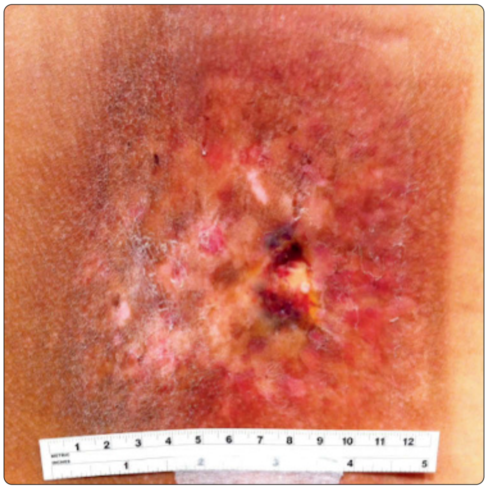


Suboptimal: Operator's Hand in Field

(Left) *The patient's arms are within the path of the radiation, unnecessarily increasing the amount of tissue imaged and thus the dose produced. Additionally, the patient is closer to the source ⇨ than to the detector ⤴, again increasing dose.* **(Right)** *The operator's hand ➡ could be excluded from this sinogram by angling the fluoroscopy beam and increasing collimation, using hemostats or towels to hold the catheter ⇒ in place, or imaging between contrast injections. The operator should consider using a ring monitor.*



Radiation-Induced Temporary Hair Loss



Radiation-Induced Skin Injury

(Left) *This patient experienced temporary hair loss due to radiation from a neurointerventional procedure. This typically occurs with an acute skin dose of 3-4 gray.* **(Right)** *Severe skin erythema and focal necrosis occurred in this patient following a complex transjugular intrahepatic portosystemic shunt (TIPS) procedure. This photograph was obtained ~ 6 months after the TIPS. Two years after the procedure, the skin has healed, but a large scar remains.*

Medications

KEY FACTS

PREPROCEDURE

- Reliable IV access almost always desired before beginning procedure
    - Allows for rapid and reliable delivery of medications
- Label all medications in procedural field
    - Color-coding syringes may also limit medication perfusion

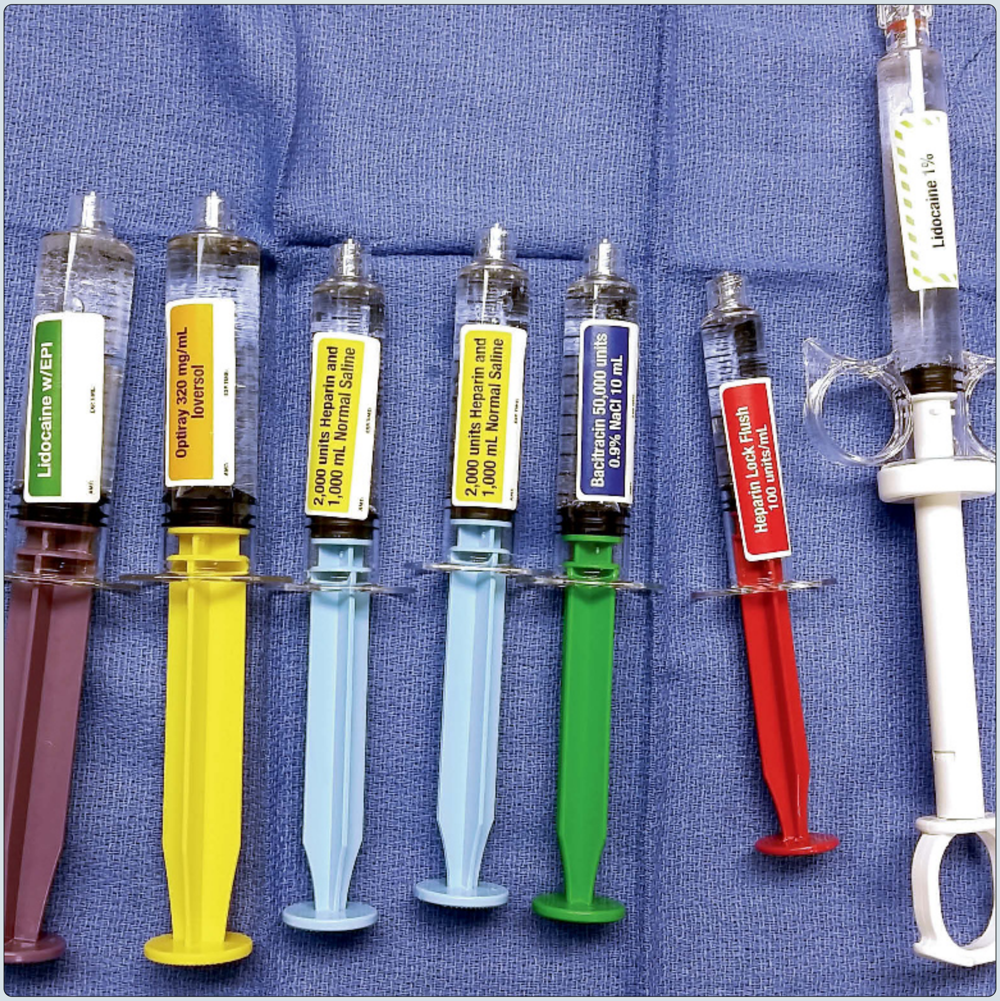
PROCEDURE

- Perform "time-out" prior to procedure
    - Confirm patient allergies
    - Provide pretreatment for contrast allergies
- Use closed-loop communication with staff to verify medications
- If medication not having expected effect, check IV tubing
    - Tubing may be disconnected, kinked, or occluded
    - IV may be infiltrating to subcutaneous tissue
    - Giving additional doses without checking tubing can result in overdosing medications
- Be prepared to treat allergic reactions to contrast or medications
- Have reversal medications available

POST PROCEDURE

- Document any new contrast or medication allergies
    - Update patient's medical record
- Monitor patients receiving sedation or analgesia
- Explain postprocedure medications to patients and their support individual(s)

Medications and Color-Coded Syringes



All medications on the sterile field are appropriately labeled. Color-coded syringes may also be used to decrease the chance of medication confusion and error.

PREPROCEDURE

Analgesia/Pain Management

- Opioids
  - Secondary effects can produce sedation
  - Monitor for respiratory depression
  - **Opioid reversal agent: Naloxone (Narcan)**
    - Typical dose 0.1-0.2 mg IV every 2-3 min
  - Fentanyl (Sublimaze): Opioid
    - Most common for interventional procedures
    - Rapid onset (within min), lasts 30-60 min
    - Typical initial dose 25-100 µg, redose as needed
  - Hydrocodone: Opioid
    - Typical dose: 5-10 mg
  - Hydromorphone (Dilaudid): Powerful opioid
    - Typical dose: 0.5-2.0 mg IV or 2-4 mg PO
  - Morphine: Opioid
    - Typical dose: 2-10 mg IV
  - Oxycodone (Roxicodone): Opioid
    - Typical dose: 5 mg PO
  - Tramadol (Ultram): Opioid for moderate pain
    - Typical dose: 50-100 mg
- Ketorolac (Toradol): Powerful NSAID
  - Typical dose: 15 mg IV q 6 hr or 10 mg PO q 4-6 hr
  - Caution in patients with renal dysfunction
  - Meperidine (Demerol): Opioid
    - Used to treat rigors
    - Typical dose: 50-150 mg IM or 25-50 mg IV

Antibiotics

- Ampicillin (Omnipen): Broad-spectrum aminopenicillin
  - Typical dose: 250-500 mg PO q 6 hr or 1-2 g IV q 4-6 hr
- Ampicillin/sulbactam (Unasyn): β-lactamase inhibitor
  - Typical dose: 1.5-3 g IV q 6 hr
- Bacitracin: Concentration of 5,000-10,000 units/mL may be flushed in port pockets or central venous catheter tunnels
- Cefazolin (Ancef): 1st-generation cephalosporin
  - Typical dose: 1-2 g IV within 1 hr of procedure
- Cefotetan (Cefotan): 2nd-generation cephalosporin
  - Typical dose: 1-2 g IV
- Cefoxitin (Mefoxin): 2nd-generation cephalosporin
  - Typical dose: 1-2 g IV
- Ceftriaxone (Rocephin): 3rd-generation cephalosporin
  - Typical dose: 1 g IV
- Ciprofloxacin (Cipro): Fluoroquinolone
  - Typical dose: 250-500 mg PO 2x daily x 5-7 days
- Clindamycin (Cleocin): Lincosamide
  - Typical dose: 600-900 mg PO or IV
  - **Alternative for patients allergic to penicillins**
- Gentamicin (Garamycin): Aminoglycoside
  - Typical dose: 1.5 mg/kg IV
  - Usually given in combination with ampicillin
    - May be given with vancomycin or clindamycin in patients allergic to penicillins
- Levofloxacin (Levaquin): Fluoroquinolone
  - Typical dose: 250-750 mg PO or IV daily
- Metronidazole (Flagyl): Nitroimidazole
  - Typical loading dose: 1 g or 15 mg/kg IV
  - Typical maintenance dose: 500 mg or 7.5 mg/kg IV or PO
- Piperacillin/tazobactam (Zosyn): Broad-spectrum penicillin with β-lactamase inhibitor
  - Typical dose 3.375 g IV
- Vancomycin (Vancocin): Glycopeptide
  - Typical dose 1 g or 15 mg/kg IV
  - **Alternative for patients allergic to penicillins**

Anticoagulant/Antiplatelet

- Clopidogrel (Plavix): Thienopyridine platelet inhibitor
  - 300 mg PO loading dose on day of stent placement
  - 75 mg PO daily following stent placement
- Enoxaparin (Lovenox)
  - Low molecular weight heparin
  - Typical dose: 40 mg subQ daily for deep vein thrombosis (DVT) prophylaxis
  - 1 mg/kg subQ 2x daily for DVT treatment
- Heparin
  - Intraprocedural dose
    - Weight-based nomogram: 80 units/kg body weight
    - Standard-care nomogram: 5,000 units IV
    - Decreased in cases of elevated prothrombin time, warfarin, or low patient weight
  - Continuous infusion
    - Weight-based nomogram: 80 units/kg body weight bolus, 18 units/kg/hr IV infusion
    - Standard-care nomogram: 5,000 units IV bolus, 800-1,600 units/hr IV infusion
    - Titrate to partial prothrombin time level of 1.5-2.5 x normal
    - Immediate onset, lasts 60-90 min
  - Monitor for heparin-induced thrombocytopenia (HIT)
  - Reversed with protamine sulfate
    - Typical dose 10 mg/1,000 units heparin, decreased based on time since last heparin administration
- Locking of central venous catheters
  - Can still cause systemic anticoagulant or allergic effects
  - Fill volume of each lumen
    - Heparin 1,000 units/mL: Can cause HIT
    - Tissue plasminogen activator: ~ 2 mg
    - Sodium citrate 4%
- Tissue plasminogen activator (Alteplase)
  - Typical dose: 0.5-1.0 mg/hr, catheter directed thrombolysis
  - Typical dose: Up to 10 mg laced into thrombus for pharmacomechanical thrombolysis
- Warfarin (Coumadin)
  - Typical initial dose: 2-5 mg daily x 1-2 days
  - Titrate dose to international normalized ratio (INR) goal, typically 2-3 for DVT &/or PE
  - Effect lasts ~ 5 days

Anxiolysis/Sedation

- Benzodiazepines
  - Monitor for respiratory depression
  - **Benzodiazepine reversal agent: Flumazenil**
    - Flumazenil (Romazicon)
      - ☐ Typical dose: 0.2 mg IV, repeated every minute as needed; maximum dose: 1 mg
  - Lorazepam (Ativan): Benzodiazepine
    - Typical dose 0.5-2.0 mg IV or PO
    - 2-4 mg IV for seizures/status epilepticus

  - Midazolam (Versed): Benzodiazepine
    - Most common medication used for sedation
    - Ensure adequate NPO status, typically 6-8 hr
    - Onset 2-4 min, lasts 45-60 min
    - Typically dosed in 0.5-1.0 mg IV boluses
    - May also give 1 mg IV for seizures
- Diphenhydramine (Benadryl): Antihistamine
  - Typical dose: 25-50 mg IV or PO

Blood Glucose Management

- Hyperglycemic management
  - Insulin: Typical dose: 5-10 units subcutaneous
    - Treatment dose variable
- Hypoglycemia management
  - Dextrose
    - Typical dose: 25 g (50 mL) of 50% dextrose (D50W) IV
    - Can also order 15-g tablets or 4 oz juice PO
  - Glucagon: Typical dose 1 mg IV, IM, or SubQ

Blood Pressure Management

- Acute antihypertensives
  - Clonidine (Catapres): Antiadrenergic
    - Typical dose: 0.1-0.2 mg PO, can repeat hourly
    - Max dose: 0.7 mg
  - Hydralazine: Vasodilator
    - Typical dose: 10-20 mg IV; onset 10-20 min
    - 10- to 80-min duration, repeat as needed
    - May increase heart rate
  - Labetalol (Trandate): Nonselective β-blocker
    - Typical dose: 20 mg IV; onset 5 (peak 10-15) min
    - Caution with COPD/asthma
    - Lowers heart rate
  - Metoprolol (Lopressor): β1-blocker
    - Typical dose: 5 mg IV; may repeat 3x
- Vasopressors
  - Dopamine (Intropin)
    - Typical dose: 5 µg/kg/min; titrate up to max 50 µg/kg/min
  - Epinephrine
    - Typical dose: 0.05-2.00 µg/kg/min; titrate to blood pressure (BP) goal
  - Norepinephrine (Levophed)
    - Initial infusion: 8-12 µg/min; titrate to BP goal
    - Typical maintenance infusion: 2-4 µg/min
  - Phenylephrine
    - Initial infusion: 100-180 µg/min; titrate to BP goal
    - Typical maintenance infusion: 40-60 µg/min

Blood Products and Volume Resuscitation

- Albumin: Volume expander
  - Available as 5% or 25%
  - Commonly given after paracentesis > 5 L
    - Typical dose: 6-8 g/L of ascitic fluid removed
  - Can also be given for hypovolemia
    - Typical dose: 25 g IV
- Cryoprecipitate
  - Contains fibrinogen, factor VIII, von Willebrand factor, and factor XIII
  - Used for deficiency of any of above factors
    - Dose varies between factors
  - Most commonly used to replace fibrinogen
    - Typical dose: 10 units for fibrinogen replacement
    - 1 unit per 5-10 kg patient weight will increase fibrinogen by ~ 50-100 mg/dL
- Fresh frozen plasma (FFP)
  - Contains all coagulation factors
  - Used to correct INR for patients taking warfarin who need emergent or urgent procedure
    - Also used on patients with multiple factor deficiencies
  - Typical dose 12-15 mL/kg body weight
    - Will increase factor levels by 20-30%
    - 1 unit = 200 mL FFP
- Normal saline: Typical bolus 1 L, often reduced in CHF
- Platelets: Typical dose: 6 units
  - Raises platelet count by ~ 30,000-60,000/µL
- Red blood cells: 1 unit increases hemoglobin by ~1 g/dL

Contrast Reaction Management

- Albuterol inhaler: β agonist
  - Typical dose 2 puffs (180 µg)
    - Can repeat up to 3x
- Dextrose
  - Multiple dose options
    - PO: 2 sugar packets, 15-g tablets, or 4-oz juice
    - IV: 1 amp (25 g) D50W
- Diphenhydramine (Benadryl): Antihistamine
  - Typical dose: 50 mg PO or IV
- Epinephrine
  - Typical dose options
    - 0.1 mg (1 mL) of 1:10,000 IV
      - Can repeat up to 1 mg total
    - 0.3 mg (0.3 mL) of 1:1,000 IM
      - Can repeat up to 1 mg total
- Furosemide (Lasix): Typical dose: 20-40 mg IV
- Glucagon: Typical dose: 1 mg IM
- Labetalol: Typical dose: 20 mg IV
- Lorazepam (Ativan): Typical dose: 2-4 mg IV
- Nitroglycerin: Typical dose: 0.4 mg sublingual
  - Can repeat every 5-10 min

Contrast Reaction Pretreatment

- ACR Manual on Contrast Media, Version 10.2
- Elective premedication
  - Option 1
    - Prednisone 50 mg PO at 13, 7, & 1 hr before contrast
    - Diphenhydramine (Benadryl) 50 mg IV or PO 1 hr before contrast
  - Option 2
    - Methylprednisolone (Medrol) 32 mg PO at 12 and 2 hr before contrast
    - Optional: Diphenhydramine (Benadryl) 50 mg IV or PO 1 hr before contrast
- Emergency premedication
  - Preferred regimen
    - Methylprednisolone sodium succinate (Solu-Medrol) 40 mg **or** hydrocortisone sodium succinate (Solu-Cortef) 200 mg IV q 4 hr until contrast given
    - Diphenhydramine (Benadryl) 50 mg IV 1 hr before contrast
  - 2nd choice regimen

    - Dexamethasone sodium sulfate (Decadron) 7.5 mg IV **or** betamethasone 6 mg IV q 4 hr until contrast
    - Diphenhydramine (Benadryl) 50 mg IV 1 hr before contrast
  - Least preferable regimen
    - Diphenhydramine (Benadryl) 50 mg IV
  - Note: IV steroids have not been proven to be effective when given < 4-6 hours prior to contrast administration

Gastrointestinal

- Antinausea/antiemetics
  - Ondansetron (Zofran): Serotonin receptor blocker
    - Typical dose: 4 mg IV, 4-16 mg PO
  - Prochlorperazine (Compazine): Antipsychotic
    - Typical dose: 5-10 mg IV or PO
  - Promethazine (Phenergan): Antihistamine
    - Typical dose: 12.5-25 mg IV or PO
    - Has sedative effect
  - Metoclopramide (Reglan): Prokinetic
    - Typical dose: 10 mg IV, 10-15 mg PO
- To halt/decrease GI peristalsis
  - Improves DSA imaging (e.g., GI bleed study)
  - Glucagon: Typical doses
    - 0.2-0.5 mg IV to decrease stomach/small bowel
    - 0.50-0.75 mg IV to decrease colonic peristalsis
    - Increases blood glucose

Heart Rate Management

- Tachycardia due to atrial fibrillation
  - Diltiazem (Cardizem): Calcium channel blocker
    - Typical dose: 20 mg IV
      - Can repeat dose with 25 q 15 min
    - Typical infusion rate: 10-15 mg/hr
  - Propranolol (Inderal): β blocker
    - Typical dose 1 mg IV
    - May repeat dose after 2 min, max dose 2 mg q 4 hr
- Bradycardia management
  - Atropine: Anticholinergic agent
    - Typical dose: 0.5-1.0 mg IV

Hyperkalemia Management

- Calcium gluconate
  - Typical dose: 500 mg to 2 g IV
- Short-acting insulin (NovoLog, Humalog)
  - Typical dose: 5-10 units IV
  - Give with sugar to prevent hypoglycemia

Local Anesthesia

- Lidocaine: Amide
  - Usually 1-2%, ± epinephrine
  - Max subcutaneous dose: 4.5 mg/kg up to 300 mg without epinephrine, 7 mg/kg up to 500 mg with epinephrine
  - Up to 10 mg may also be given intraarterially prior to embolization (e.g., uterine artery embolization, chemoembolization)
- Chloroprocaine: Ester
  - May be used for patients with lidocaine allergies
  - Max subcutaneous dose: 11 mg/kg up to 800 mg without epinephrine, 14 mg/kg up to 1,000 mg with epinephrine
- Diphenhydramine (Benadryl): Antihistamine
  - 1% solution may be used in patients allergic to amide and ester local anesthetics
  - Monitor for sedative effects

Miscellaneous

- Octreotide: Somatostatin analog
  - Prior to adrenal biopsy, chemoembolization of hormonally active neuroendocrine tumors
    - 200 μg subcutaneous

Reversal Agents

- Benzodiazepine reversal
  - Flumazenil (Romazicon): Benzodiazepine antagonist
    - Typical dose: 0.2 mg IV every min
      - Repeat dose every 1 min for max dose of 1 mg
    - **May be shorter acting than benzodiazepines**
      - Monitor patient closely
- Heparin reversal
  - Protamine sulfate
    - Typical dose: 10 mg/1,000 units heparin given
      - Dose may be decreased based on time since last heparin administration
- Opioid reversal
  - Naloxone (Narcan): Opioid antagonist
    - Typical dose: 0.1-0.2 mg IV every 2-3 min
    - **Often shorter acting than opioids**
      - **Patient must be closely monitored and may need multiple doses**
    - May cause nausea, withdrawal
- Warfarin reversal
  - Vitamin K (phytonadione)
    - Typical dose: 1.0-2.5 mg PO
  - FFP for emergent reversal

Sclerosants

- Some can be mixed with air to create foam
  - Improves surface contact and reduces sclerosant dose
- Sodium tetradecyl sulfate (STS) (Sotradecol)
  - Typically use 3% concentration
  - Foam mixture: 3 (air): 2 (STS): 1 (lipiodol)
  - Typical dose: ≤ 2 mL
- Bleomycin
  - Typical dose: 1 unit/cc foam (e.g., 6 units bleomycin in 1 mL saline + 1 mL albumin + 4 mL air)
- Ethanol: Strong sclerosant, use caution
  - Typical dose: 25-50% of estimated volume to sclerose
  - Nerve damage and necrosis of skin/mucosa possible
- Additional sclerosants available

Vasospasm Management

- Nitroglycerin: Vasodilator
  - Typical dose 100-200 μg IV or IA
- Verapamil: Calcium channel blocker
  - Typical dose: 2.5 mg IV

SELECTED REFERENCES

1. American College of Radiology Manual on Contrast Media. V10.2 https://www.acr.org/quality-safety/resources/contrast-manual. Reviewed March 28, 2017. Accessed March 28, 2017.

Recommendations for Administration of Prophylactic Antibiotics

Procedure	Routine Prophylaxis Recommended?	Antibiotic Options
Angiography, angioplasty, stenting	No	1 g cefazolin (Ancef)
Inferior vena cava filter placement	No	
Embolization, hepatic (bland or chemoembolization)	Yes	1.5-3.0 g ampicillin/sulbactam (Unasyn) IV; 1 g cefazolin (Ancef) IV and 500 mg metronidazole (Flagyl) IV; 2 g ampicillin (Principen) IV and 1.5 mg/kg gentamicin (Garamycin) IV; 1 g ceftriaxone (Rocephin) IV
Embolization, renal or splenic	Yes	1 g ceftriaxone (Rocephin) IV
Uterine artery embolization	Yes	1 g cefazolin (Ancef) IV; 900 mg clindamycin (Cleocin) IV and 1.5 mg/kg gentamicin (Garamycin) IV; 2 g ampicillin (Principen) IV; 1.5-3.0 g ampicillin/sulbactam (Unasyn) IV
Transjugular intrahepatic portosystemic shunt	Yes	1 g ceftriaxone (Rocephin) IV; 1.5-3.0 g ampicillin/sulbactam (Unasyn) IV
Gastrostomy/gastrojejunostomy placement	Yes if pull technique, no consensus if push technique	1 g cefazolin (Ancef) IV
Hepatobiliary interventions	Yes	1 g ceftriaxone (Rocephin) IV; 1.5-3.0 g ampicillin/sulbactam (Unasyn) IV; 2 g ampicillin (Principen) IV and 1.5 mg/kg gentamicin (Garamycin) IV
Genitourinary interventions	Yes	1 g cefazolin (Ancef) IV; 1 g ceftriaxone (Rocephin) IV; 1.5-3 g ampicillin/sulbactam (Unasyn) IV; 2 g ampicillin (Principen) IV and 1.5 mg/kg gentamicin (Garamycin) IV
Tumor ablation	No consensus	Liver: 1.5-3.0 g ampicillin/sulbactam (Unasyn) IV; renal or bone: 1 g ceftriaxone (Rocephin) IV
Abscess drainage	Yes	1-2 g cefoxitin (Mefoxin) IV q 6 hr; 1-2 g cefotetan (Cefotan) IV q 12 hr; 3 g ampicillin/sulbactam (Unasyn) IV q 6 hr; 3.375 g piperacillin/tazobactam (Zosyn) IV
Percutaneous biopsy	Not unless biopsy transrectal	80 mg gentamicin (Garamycin) IV/IM plus 250 mg ciprofloxacin (Cipro) PO 2x daily x 5 days
Vertebral body augmentation	Yes	1 g cefazolin (Ancef) IV
Patients with penicillin allergies may be given vancomycin or clindamycin as well as an aminoglycoside antibiotic, such as gentamicin.		

Adapted from: Venkatesan AM et al: Practice guidelines for adult antibiotic prophylaxis during vascular and interventional radiology procedures. J Vasc Interv Radiol. 21(11):1611-30; 2010.

Antibiotic Classes and Coverage

Antibiotic Class	Example Medication	Coverage
Aminoglycosides	Gentamicin	gram-negative aerobes, *Pseudomonas*
Cephalosporins: 1st generation	Cefazolin	Skin flora, including *Staphylococcus aureus*, basic gram negative
Cephalosporins: 2nd generation	Cefoxitin	Decreased *S. aureus* coverage compared to 1st generation but better gram-negative coverage and some anaerobic coverage
Cephalosporins: 3rd generation	Ceftriaxone	Decreased coverage of gram positives, including *S. aureus* compared to 1st and 2nd generations but with improved gram-negative coverage and some coverage of *Pseudomonas*
Cephalosporins: 4th generation	Cefepime	Similar to 3rd generation but with improved *Pseudomonas* coverage
Glycopeptide	Vancomycin	gram positive, *Streptococcus*, *Staphylococcus*, MRSA
Lincosamide	Clindamycin	MRSA, anaerobes

Antibiotic Classes and Coverage (Continued)

Antibiotic Class	Example Medication	Coverage
Penicillins: 3rd generation	Ampicillin	*Streptococcus*, basic gram negative
Penicillins: 4th generation	Piperacillin	*Pseudomonas*
Quinolones: 2nd generation	Ciprofloxacin	gram negative, *Pseudomonas*, *S. aureus* (not MRSA)
Quinolones: 3rd generation	Levofloxacin	gram negative, *Pseudomonas*, gram positive, *S. aureus* (not MRSA)
Nitroimidazole	Metronidazole	Anaerobes

Treatment of Contrast Reactions

Symptoms	Treatment
All reactions	Maintain IV access Monitor vitals Provide supplemental O_2 as needed Call rapid response, code, or 911 as needed
Anxiety (diagnosis of exclusion)	Reassure patient
Bronchospasm	Mild: 2 puffs (180 μg) albuterol inhaler Moderate: Albuterol plus consider 0.1 mg (1 mL) epinephrine 1:10,000 IV **or** 0.3 mg (0.3 mL) epinephrine 1:1,000 IM Severe: Albuterol **and** 0.1 mg (1 mL) epinephrine 1:10,000 IV **or** 0.3 mg (0.3 mL) epinephrine 1:1,000 IM Call rapid response, code, or 911 as needed
DIffuse erythema	6-10 L/min O_2
Hives	25-50 mg diphenhydramine (Benadryl) PO or IV
Hypoglycemia	6-10 L/min O_2 If patient can safely swallow: Oral glucose (2 sugar packets or 15 g of tablets or 4 oz fruit juice) If patient unable to safely swallow: 1 amp (25 g) D50W IV Unable to swallow and no IV access: 1 mg glucagon IM
Hypotension	1 L bolus of normal saline Elevate legs If unresponsive to fluids: 0.1 mg (1 mL) epinephrine 1:10,000 IV (preferred) **or** 0.3 mg (0.3 mL) epinephrine 1:1,000 IM Call rapid response, code, or 911 as needed
Hypotension with bradycardia (vasovagal)	If unresponsive to fluids and supplemental oxygen: 0.6-1.0 mg atropine IV
Hypotension with tachycardia (anaphylaxis)	0.1 mg (1 mL) epinephrine 1:10,000 IV (preferred) **or** 0.3 mg (0.3 mL) epinephrine 1:1,000 IM Call rapid response, code, or 911 as needed
Hypertensive crisis	6-10 L/min O_2 20 mg labetalol IV **or** 0.4 mg nitroglycerin sublingual **and** 20-40 mg furosemide (Lasix) IV Call rapid response, code, or 911 as needed
Laryngeal edema	6-10 L/min O_2 0.1 mg (1 mL) epinephrine 1:10,000 IV **or** 0.3 mg (0.3 mL) epinephrine 1:1,000 IM Call rapid response, code, or 911 as needed
Pulmonary edema	6-10 L/min O_2 Elevate head of bed 20-40 mg furosemide (Lasix) IV Call rapid response, code, or 911 as needed
Seizures	Protect patient and turn on side Suction airway as needed 6-10 L/min O_2 If not resolving spontaneously: 2-4 mg lorazepam (Ativan) IV Call rapid response, code, or 911 as needed

Adapted from American College of Radiology Manual on Contrast Media. V10.2 https://www.acr.org/quality-safety/resources/contrast-manual. Reviewed March 28, 2017. Accessed March 28, 2017.

KEY FACTS

TERMINOLOGY

- **Angioplasty**: Inflation of catheter-mounted balloon within narrowed vessel; controlled fracture of obstructing plaque enlarges lumen, improves flow

PROCEDURE

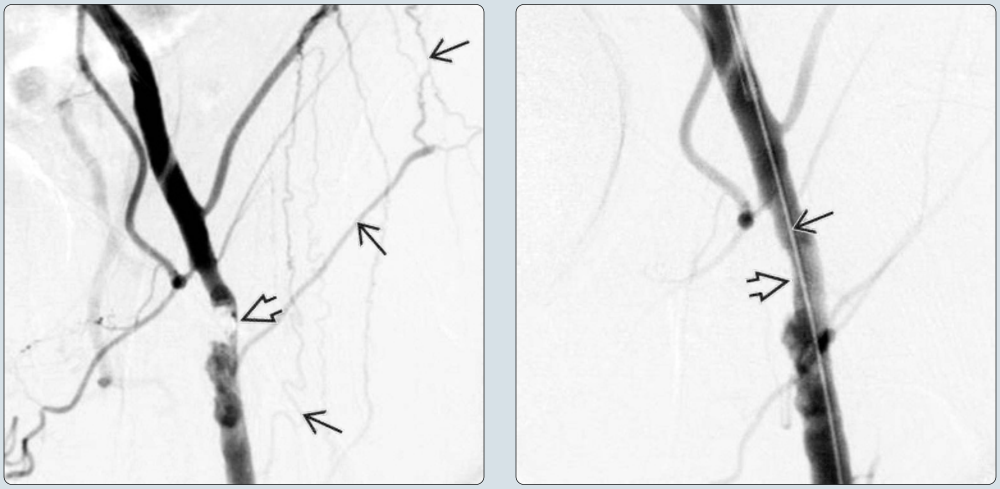
- Selectively catheterize target artery/vein
  - Administer heparin bolus prior to crossing lesion
- Gently advance guidewire across stenosis
  - Imperative to avoid dissection
  - If resistance to guidewire passage, do not continue to advance wire; stop, reorient wire/catheter
  - Keep catheter parallel to vessel centerline
- Advance diagnostic catheter over wire, across lesion
  - Exchange crossing wire for stiff guidewire
- Replace diagnostic catheter with PTA catheter
  - Perform angioplasty; use insufflator
- Remove PTA catheter, leave guidewire across lesion
  - Document results with DSA imaging

POST PROCEDURE

- Consider antiplatelet regimen after arterial procedure
- Consider anticoagulant regimen after venous procedure
- Arrange patient follow-up
  - Order imaging/noninvasive studies as needed
  - Schedule clinical appointment

OUTCOMES

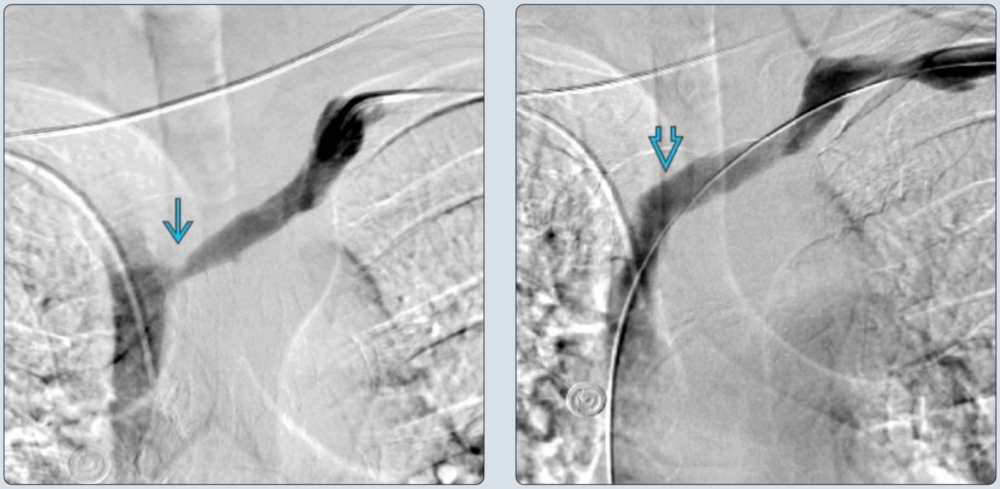
- Technical and clinical success rates depend on
  - Lesion length, location, morphology; runoff status
  - Restenosis (rate may be up to 40%)
  - Drug-eluting balloon restenosis rates may be favorable to conventional angioplasty
- Most significant potential complications
  - Vessel rupture (reinflate balloon to stabilize)
  - Distal embolization, thrombosis



Common Femoral Artery Eccentric Stenosis (Pre-Angioplasty)

Common Femoral Artery Eccentric Stenosis (Post Angioplasty)

(Left) *Anteroposterior DSA of the left common femoral artery shows a focal, eccentric, high-grade stenosis* ⇨*. Note the numerous collaterals* → *that are present, further confirming the significance of the stenosis.* **(Right)** *Postangioplasty DSA shows a normal luminal caliber at the site of prior stenosis* ⇨*. A guidewire* → *was left in place across the stenosis until angiographic confirmation of a satisfactory result. The collaterals no longer fill.*



Symptomatic Central Venous Stenosis of Hemodialysis (Pre-Angioplasty)

Symptomatic Central Venous Stenosis of Hemodialysis (Post Angioplasty)

(Left) *Angioplasty, with or without stent placement, is the recommended treatment for symptomatic central venous stenosis (CVS)* → *by the Kidney Disease Outcomes Quality Initiative (K/DOQI).* **(Right)** *PTA has high initial angiographic success (70-90%)* ⇨*. However, PTA disrupts the vessel intima and triggers accelerated neointimal hyperplasia (i.e., recurrent stenosis). Also, CVS primary stenting does not improve primary patency vs. PTA. Thus, avoid any intervention in asymptomatic patients.*

TERMINOLOGY

Definitions

- **Percutaneous transluminal angioplasty (PTA)**: Inflation of catheter-mounted balloon within narrowed vascular structure to enlarge luminal diameter, improve flow hemodynamics
  - Arterial angioplasty: Primary mechanism is controlled fracture of obstructing atherosclerotic plaque
    - Desquamation of endothelial cells
    - Causes fissures in plaque/intima; stretches media
      - Virtually no compression of plaque itself
  - Venous angioplasty: PTA of stenotic venous lumen
    - Stretches entire vein wall, usually without fissures
    - Often requires high-pressure balloon
  - Stent associated: PTA often performed in conjunction with stenting
    - Predilation PTA of stenosis, allowing stent advancement into position
    - Postdeployment PTA, maximally distending & securing stent
  - Post angioplasty: In weeks following PTA, reendothelialization of intima occurs; vessel remodels
    - Post-PTA restenosis due to prolific neointimal hyperplasia &/or major vascular remodeling (e.g., recoil); largely an inflammatory response
- Angioplasty catheter designs
  - **Over-the-wire (OTW)**: Central lumen for guidewire access/contrast injection, small parallel lumen within catheter for balloon inflation/deflation
    - Traditional angioplasty balloon catheter design
    - Guidewire in central lumen improves catheter tracking & pushability
    - Contrast can be injected through catheter
  - **Rapid exchange (monorail)**: Guidewire passes through balloon, exits catheter proximal to balloon, runs outside catheter shaft
    - Increasingly popular angioplasty catheter
    - Exchange length guidewires unnecessary
    - Balloon typically has lower profile
    - Rapid balloon inflation/deflation times
    - Often used with guide-catheter/sheath to minimize following disadvantages
      - Unable to inject contrast through catheter
      - Poorer trackability/pushability than OTW
- Various angioplasty technologies/techniques
  - **Conventional, a.k.a. plain old balloon angioplasty (POBA)**: Balloon inflation within narrowed lumen
    - Outward force (measured in atmospheres) exerted by balloon against obstructing lesion/stenosis
    - Degree of force depends on
      - Diameter, compliance (elasticity), inflation pressure, and length of angioplasty balloon
      - Severity and morphology of stenosis
  - **Cutting balloon angioplasty**: 3-4 atherotomes (microsurgical blades) fixed longitudinally on surface of noncompliant balloon
    - Atherotomes expand radially, delivering longitudinal incisions in plaque & vessel
      - Theoretically reduces vessel stretch/injury by scoring plaque vs. uncontrolled disruption
      - Randomized trial of 1,385 coronary lesions: No clinical or angiographic difference between cutting & standard PTA at 6-month follow-up
      - Some small studies suggest lower restenosis rates
      - Generally infrequently used for arterial lesions
      - Most frequently used for PTA of venous stenoses
  - **Scoring balloon angioplasty**: Balloon surrounded by wire "cage" for focally concentrated dilatation
    - AngioSculpt scoring balloon (AngioScore): Semicompliant balloon encircled by 3-4 nitinol spiral struts
      - Balloon inflation focuses radial force along edges of struts, scoring plaque circumferentially
      - Similar technology to cutting balloon angioplasty; wires rather than blades
    - VascuTrak PTA balloon (Bard Peripheral Vascular): 2 flexible longitudinal wires externally parallel semicompliant balloon
      - Flexible wires score plaque in tortuous vessels
      - 0.014"/0.018" rapid exchange system
      - Balloon lengths from 20-300 mm
  - **Cryoplasty**: Combines angioplasty with cold energy to treat obstructive atherosclerotic plaque
    - PolarCath peripheral dilation catheter (Boston Scientific)
    - Liquid nitrous oxide used to inflate balloon while lowering its surface temperature to -10°C
      - Theoretically causes altered plaque response, decreased elastic recoil, cellular apoptosis
    - Recent trials indicate cryoplasty does not offer outcomes superior to balloon angioplasty
      - Unfavorable cost-benefit
      - Possibly higher restenosis rates
  - **Drug-eluting balloon angioplasty**: Balloon coated with medication (e.g., paclitaxel)
    - Delivers antiproliferative drug to vessel surface
      - Local drug application to vessel surface to prevent restenosis without placing stent
      - High drug concentration reduces neointimal proliferation even with short time exposure
    - Investigational device with ongoing trials

PREPROCEDURE

Indications

- Hemodynamically significant stenosis or obstruction
  - May initially evaluate with noninvasive imaging
    - Noninvasive studies (duplex Doppler, CT, MR)
  - Reasonable likelihood PTA will improve symptoms
  - PTA is most appropriate treatment option

Contraindications

- Arterial angioplasty alone may be unsafe or ineffective if
  - Diffuse atherosclerotic disease
    - Long segment stenosis/occlusion
    - Eccentric, heavily calcified plaque
      - Bulky, polypoid plaque; thrombus or embolus associated with lesion
      - Risk of distal embolization
  - Stenosis adjacent to aneurysm (risk of rupture)
- Venous angioplasty may be ineffective if

  - Stenosis due to extrinsic compression
  - Chronic venous occlusion/postthrombotic

Getting Started

- Things to check
  - Clinical history and physical examination
    - Emphasis on risk factors for peripheral artery disease
    - Detailed pulse examination/Doppler evaluation
    - Current medications
      - Any anticoagulants, antiplatelet agents, oral hypoglycemic agents, antihypertensives
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - Complete blood count (CBC)
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ratio (INR) ≤ 1.5
      - Normal prothrombin time (PT), partial thromboplastin time (PTT)
  - Limit oral intake: NPO for 8° prior to procedure
    - If moderate sedation/general anesthesia planned
    - Take any oral medications with water sip
- Medications
  - Heparin [typically 2,500-5,000 unit bolus (IV or IA)]
    - Usually administered prior to crossing lesion
    - May be continued post procedure (weight-based protocol)
  - Vasodilator (e.g., nitroglycerin, typically 100 μg IA bolus)
    - Prevents/treats catheter-induced vasospasm
  - Clopidogrel (300 mg loading, 75 mg daily dose for 4-6 weeks minimum)
    - May electively give loading dose before procedure
  - Conscious sedation (typically fentanyl & midazolam)
  - Local analgesia (typically 1-2% lidocaine)
- Equipment list
  - Vascular access sheath
    - Size based on balloon requirements
  - Guidewires
    - 0.035" guidewire
    - Angled or straight-tipped hydrophilic guidewire
      - Often beneficial for crossing lesion
      - Guidewire diameter depends on balloon system chosen (e.g., 0.018" vs. 0.035")
    - Stiff guidewire (e.g., Amplatz, Lunderquist, McNamara, Rosen)
      - Stability when advancing balloon across lesion
      - Exchange length needed for distal lesions
  - Catheters
    - Guiding catheter/sheath; often used coaxially with rapid exchange system
      - Allows contrast injection around angioplasty catheter; precisely targets lesion
      - Provides stability when advancing system
    - Diagnostic flush catheter (e.g., pigtail)
    - Selective catheter (e.g., Cobra, Simmons)
    - Angioplasty balloon catheter
      - High-pressure vs. low-pressure balloon
      - Specialty balloon (e.g., drug eluting, scoring)
      - Balloon diameter, length based on target lesion
      - System (e.g., 0.018" vs. 0.035")
    - Insufflator: permits calibrated balloon inflation
    - Radiographic contrast medium
    - Heparinized saline flush solution
      - Concentrations range from 5-20 units/mL

PROCEDURE

Equipment Preparation

- Do not "test" balloon by inflating
  - Balloon "wrapped" around catheter; predilated low profile best to cross lesion

Procedure Steps

- Obtain vascular access
- Introduce vascular access sheath over guidewire
- Obtain diagnostic angiogram; evaluate target lesion
- Consider coaxial guiding catheter/sheath (typically 5 or 6 Fr)
  - Allows contrast injection during balloon advancement; precisely localizes lesion during PTA
  - Typically used with smaller system (0.014" or 0.018")
    - 4- or 5-Fr inner selective catheter
    - Ideal for rapid exchange (monorail) balloons
  - Introduce selective catheter coaxially through guiding catheter/sheath
- If no coaxial sheath, exchange diagnostic for selective catheter
- Position selective catheter proximal to target stenosis
- Administer heparin bolus prior to crossing lesion
  - 2,500-5,000 unit bolus (IV or IA)
- Advance wire beyond stenosis
- Gently advance guidewire across stenosis
  - Imperative to avoid vessel dissection
  - Keep catheter parallel & centered in vessel, directing guidewire centrally (even with eccentric stenosis)
  - If resistance to guidewire passage, do not force (may cause dissection)
    - Retract wire, reorient catheter, readvance wire
    - Consider different catheter shape, different guidewire, smaller caliber wire/catheter
  - Maintain visualization of wire tip (prevents organ/vessel branch perforation)
- Advance selective catheter over wire, across lesion
  - Once catheter beyond lesion, inject contrast to confirm intraluminal location
  - Exchange for stiff wire (e.g., Amplatz, McNamara, Lunderquist, Rosen)
- Exchange selective catheter for angioplasty catheter
  - Base balloon size on adjacent normal vessel diameter
    - **Caution**: Do not significantly oversize balloon (risks vessel rupture, accelerated intimal hyperplasia & subsequent vessel restenosis)
  - Maintain guidewire position across lesion
  - Center angioplasty balloon within lesion, exposing lesion to greatest radial force
- Perform angioplasty
  - Use insufflator for balloon inflation (high-pressure, calibrated inflation)
  - Inflate balloon with 50/50 contrast/saline mix
    - Fluid generates greater radial force than air

    - 100% contrast too viscous for rapid balloon inflation/deflation; also too radiopaque
  - Balloon "waist" typically created by stenosis
    - With continued inflation, waist should release
      - Release of waist implies correction of stenosis
- Deflate, remove angioplasty balloon catheter
  - **Caution**: Do not remove guidewire at this time
    - Vessel dissection & active hemorrhage can occur post PTA; maintaining wire permits rapid reintroduction of balloon to stabilize vessel rupture
    - Repeat PTA or stenting may be necessary
    - Recrossing "fresh" angioplasty site with guidewire can easily cause dissection
  - Inject contrast through guiding catheter/sheath
    - Document angioplasty result
    - Determine if further intervention indicated
      - Consider repeat PTA with larger diameter balloon
      - Consider stenting if poor PTA result
    - Document status of distal vessels/organs after PTA
  - If satisfactory result, carefully withdraw guidewire
  - Remove guiding catheter/sheath (push reverse-curve catheters out of vessel, pull other catheter shapes)
  - Close access site
    - Manual compression: Remove access sheath, compress puncture site (15 minutes graded compression for arteries)
    - Closure device: Per device instructions

Alternative Procedures/Therapies

- Radiologic
  - Atherectomy
    - Used in conjunction with PTA/stent placement
  - Primary stent placement
    - Risk stent fracture, difficult-to-treat in-stent restenosis
    - Drug-eluting stents typically reduce restenosis rates vs. bare-metal stents
- Surgical
  - Bypass surgery, endarterectomy

POST PROCEDURE

Things to Do

- Consider antiplatelet regimen after arterial procedure
- Consider anticoagulant regimen after venous procedure
- Clinically follow patient
  - Depending on lesion treated, may obtain
    - Noninvasive arterial studies (impedance plethysmography, pulse volume recording, segmental limb pressures; ankle-brachial index)
    - Duplex Doppler evaluation
    - CTA/CTV, MRA/MRV

OUTCOMES

Complications

- Most feared complication(s)
  - Rupture of target artery or vein
    - Potentially fatal
      - Maintain guidewire access across lesion
      - Stabilize with immediate balloon reinflation
      - Fluid resuscitate, call code team as needed
      - Requires covered stent or surgical repair
- Immediate/periprocedural complication(s)
  - Distal embolization (2-8% incidence)
    - Usually asymptomatic microscopic debris
    - Macroscopic embolization may occur
    - Cholesterol embolization (incidence < 1%)
      - Cholesterol crystals embolize after contact of catheter/guidewire with soft, lipid-rich plaque
      - Lodge in arterioles; inflammation/occlusion
      - Can cause tissue ischemia and necrosis
      - May lead to amputation, bowel ischemia, stroke, permanent renal failure, death
  - Flow-limiting dissection or intimal flap
    - Treat with stent placement
  - Immediate or delayed thrombosis at PTA site (5%)
    - Minimize with antiplatelet/anticoagulation agents
- Delayed complication(s)
  - Restenosis (rate may be up to 40%)
    - Dependent on lesion length, location, severity, morphology; choice of balloon
    - Repeat POBA or drug-eluting balloon
    - Place stents (drug-eluting, bare metal, covered)
- Other complications
  - Access site complications (hematoma, iatrogenic arteriovenous fistula, pseudoaneurysm)
  - Contrast-induced nephropathy

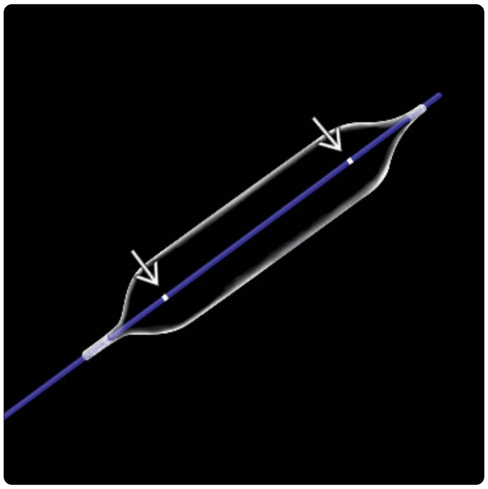
Expected Outcomes

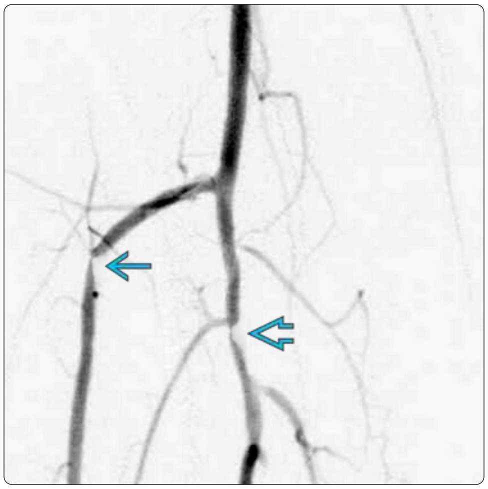
- High initial technical success rate
  - Initial technical success depends on
    - Anatomic location of lesion (e.g., iliac, femoral)
    - Length of occlusion/stenosis (TASC classification)
    - Lesion morphology (e.g., eccentric, calcified)
- Long-term technical and clinical results depend on
  - Same factors as for initial success rates
  - Quality of distal runoff
  - Relevant risk factors
    - Tobacco use, diabetes, hyperlipidemia
  - Neointimal hyperplasia
- DEB for treatment of PAD
  - Femoropopliteal
    - Initial success: Up to 95% (POBA/stents similar)
      - 12-month restenosis: 40-60% for POBA (25-40% for stents)
    - DEB (paclitaxel): 65-90% primary patency at 1 year
    - Data lacking regarding DEB vs. bare-metal/drug-eluting stents
  - Infrapopliteal & chronic limb ischemia (CLI)
    - 2 RCT suggest no difference DEB vs. POBA at 12 months
    - Nearly 1/2 of patients require major amputation within 1 year: Suggests short-term improvement (tissue oxygenation, wound healing, limb salvage) priority over long-term patency

SELECTED REFERENCES

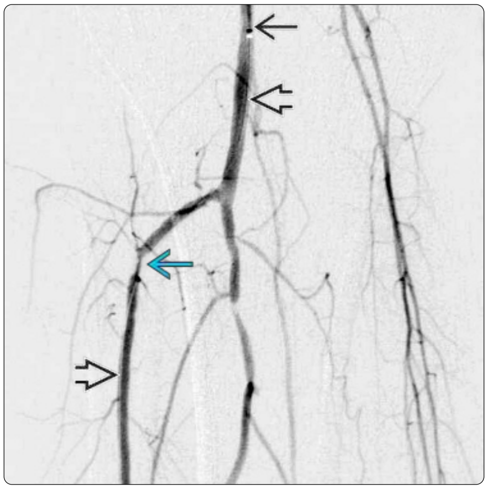
1. Naghi J et al: New developments in the clinical use of drug-coated balloon catheters in peripheral arterial disease. Med Devices (Auckl). 9:161-74, 2016
2. Diehm NA et al: Drug eluting balloons. Tech Vasc Interv Radiol. 13(1):59-63, 2010

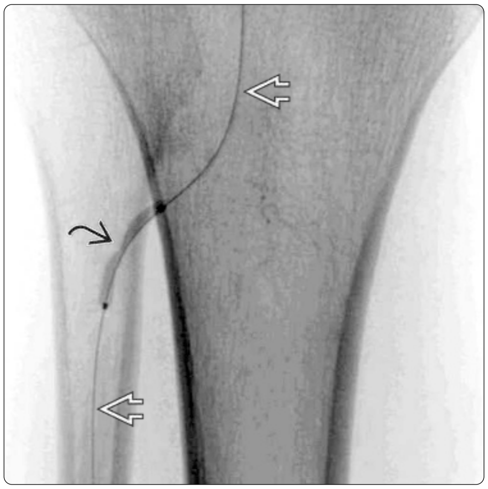
(Left) *Photograph of an inflated angioplasty balloon shows radiopaque markers* ➡ *denoting margins beyond which the balloon tapers. These markers facilitate optimal positioning of the balloon during PTA.* **(Right)** *A diabetic patient with rest pain and an ischemic foot ulcer underwent angiography. An infrapopliteal runoff shows high-grade stenoses of the anterior tibial* → *and peroneal* ⇨ *arteries.*


Angioplasty Balloon

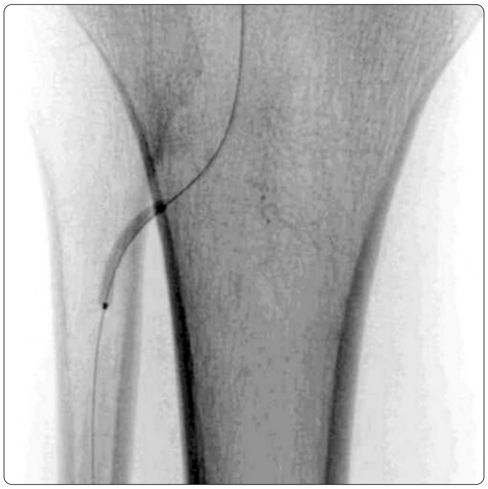

Conventional Balloon Angioplasty

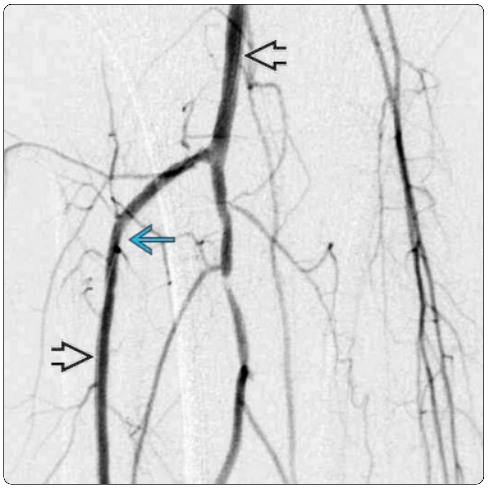
(Left) *A 3-Fr catheter* → *was advanced to the infrapopliteal artery. After administering 5,000 units of heparin, a guidewire* ⇨ *was advanced across the anterior tibial stenosis* →*. 0.014" diameter guidewires are often used in infrapopliteal vessels.* **(Right)** *An angioplasty balloon has been advanced over the wire* ➡*, positioned to bridge the stenosis, and inflated. A waist* ↷ *indents the balloon at the level of the stenosis. The balloon diameter was based upon measurements of the target vessel.*


Conventional Balloon Angioplasty

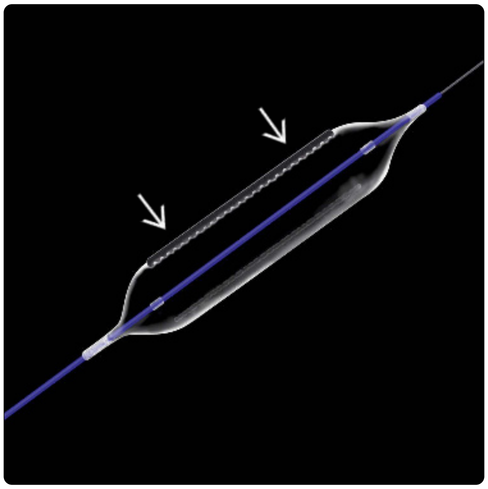

Conventional Balloon Angioplasty

(Left) *With continued balloon inflation, using an insufflator to achieve ~ 10 atmospheres of pressure, the "waist" is eliminated, which is necessary for successful angioplasty.* **(Right)** *DSA after balloon removal shows a normal vessel caliber where a stenosis was previously seen* →*. The guidewire* ⇨ *was left in place across the stenosis until DSA confirmed a good result. This allows continued access across the lesion in the event that additional treatment is necessary, or in case a complication occurs.*

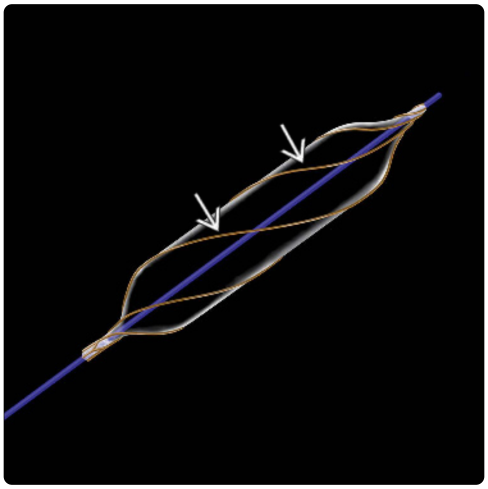

Conventional Balloon Angioplasty


Conventional Balloon Angioplasty

Cutting Balloon

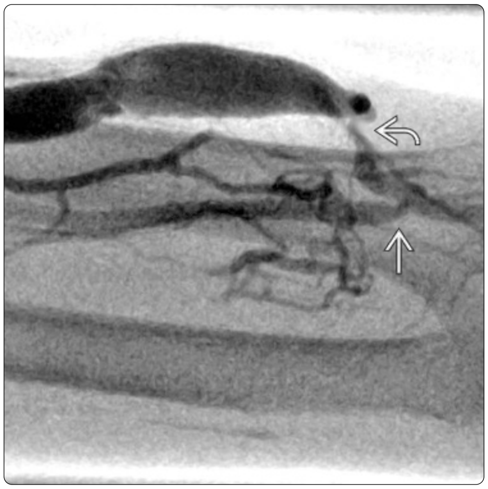


Scoring Balloon

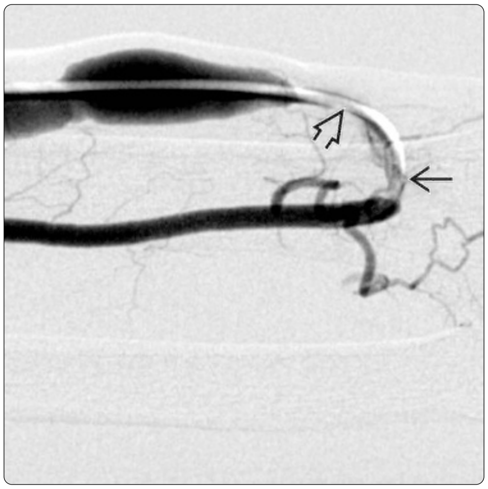


(Left) *Microsurgical blades (atherotomes) → are fixed longitudinally to the surface of a noncompliant angioplasty balloon, which upon inflation expands radially, delivering incisions into the plaque.* **(Right)** *The semi-compliant balloon is encircled by flexible rectangular nitinol struts →. The design is intended to focus uniform radial force along the edges of the nitinol, scoring the plaque and resulting in a more precise and predictable angioplasty outcome.*

Scoring Balloon Angioplasty

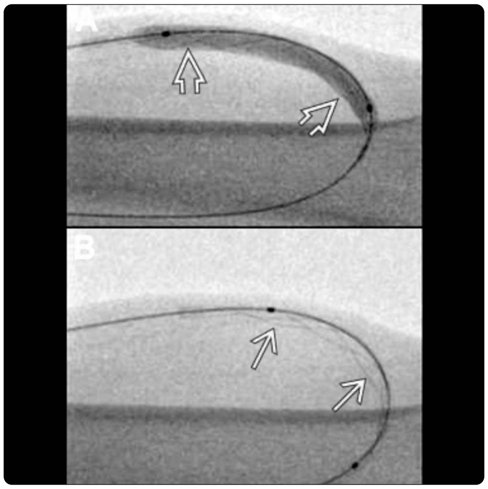


Scoring Balloon Angioplasty

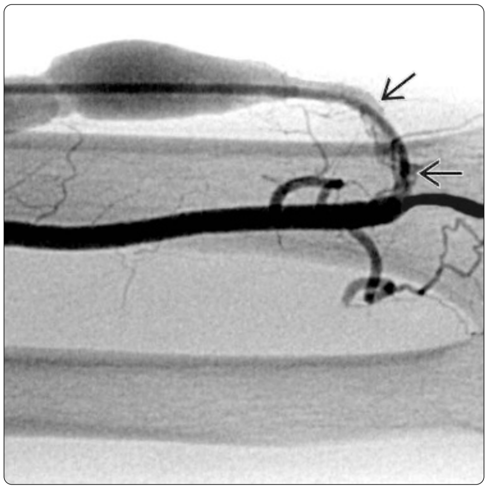


(Left) *Evaluation of a failing hemodialysis fistula shows stenosis at the arteriovenous anastomosis → and an adjacent stenotic lesion ↪ within the fistula. The fistula was nonpulsatile, with poor flow.* **(Right)** *Following conventional angioplasty with a high-pressure balloon, there is only minimal improvement of the previously demonstrated venous stenoses →. The luminal diameter approximates that of the catheter ⇨ that lies within the vessel.*

Scoring Balloon Angioplasty

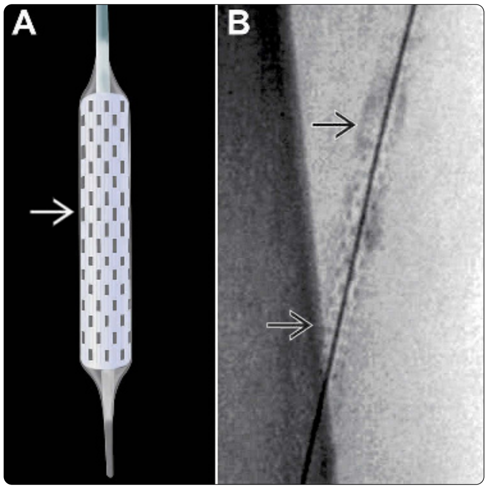


Scoring Balloon Angioplasty

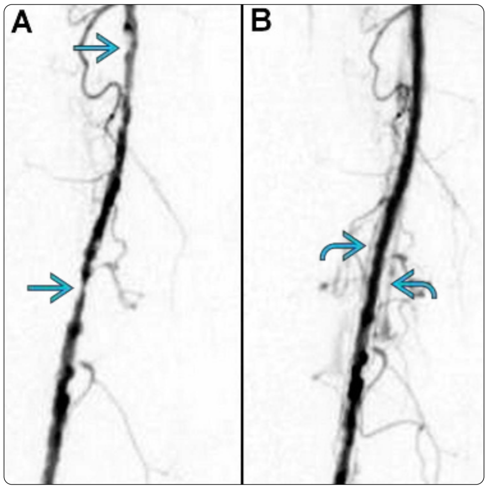


(Left) *(A) Subsequently, repeat angioplasty was performed with a scoring balloon ⇨. (B) It was hoped that the additional force from the nitinol struts → encircling the balloon would yield a more satisfactory result than that of the initial conventional venous angioplasty.* **(Right)** *Venography following the scoring balloon angioplasty shows a marked improvement in the appearance of the previously noted venous stenoses →. A palpable thrill was present in the fistula afterward.*

(Left) *Graphic (A) shows a cryoplasty balloon ➡ inflated with liquid nitrous oxide, lowering its temperature to -10°C, theoretically causing altered plaque response, decreased recoil, and cellular apoptosis, with the goal of reducing restenosis. Fluoroscopic image (B) shows an inflated cryoplasty balloon ⇨. Note the distinctive balloon markings.* **(Right)** *Diffuse SFA stenosis ➡ is shown before (A) and after (B) cryoplasty. After cryoplasty, vessel diameter is improved, but fine dissection channels ↪ parallel the treated zone.*

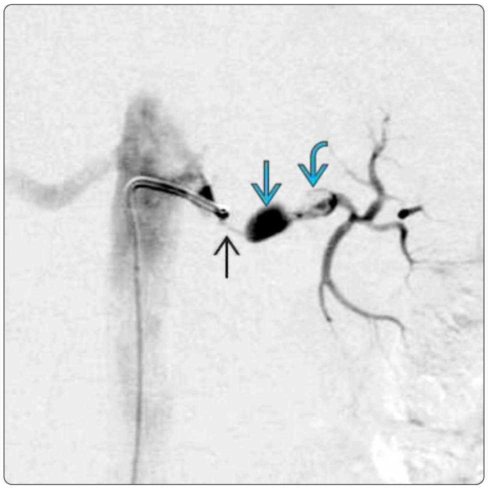


Cryoplasty Balloon

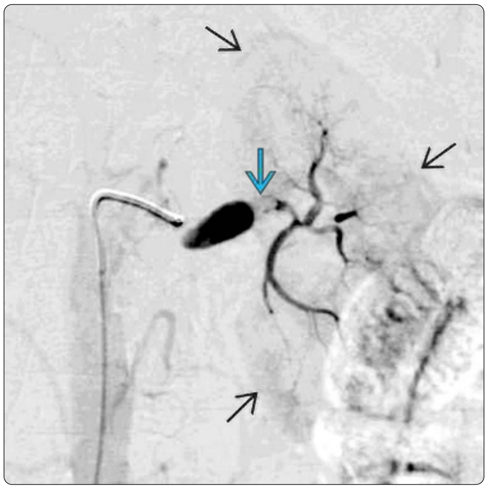


Cryoplasty

(Left) *A selective left renal arteriogram shows a proximal high-grade stenosis → with either marked poststenotic dilatation or an aneurysm distal to the stenosis ➡. There is also a distal filling defect ↪, which appears to represent aneurysmal thrombus.* **(Right)** *DSA imaging later in the arterial phase of the injection shows an early nephrogram →, filling of distal intrarenal arterial branches, and persistence of the filling defect ➡. The findings in these images are atypical for an atherosclerotic renal artery stenosis.*

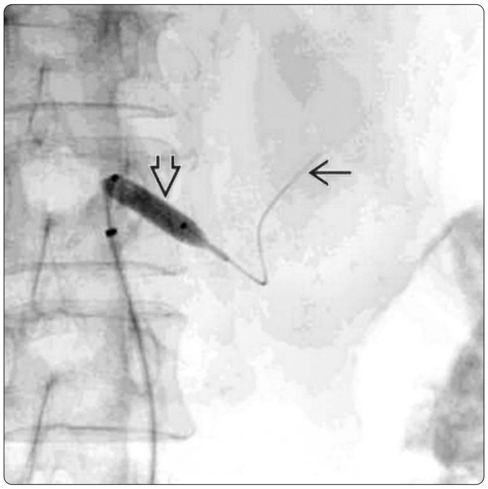


Complication of Angioplasty

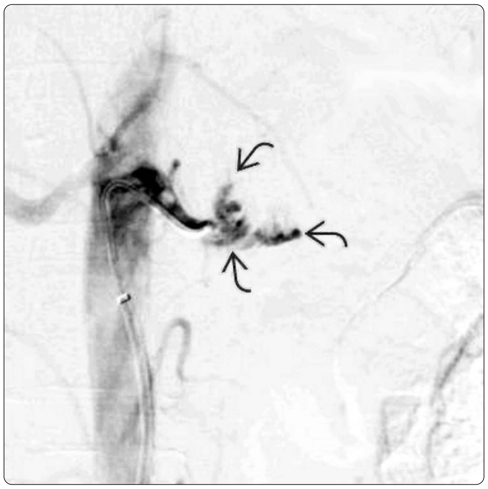


Complication of Angioplasty

(Left) *Angioplasty was performed with a slightly oversized balloon ⇨ over a guidewire →.* **(Right)** *Post-PTA contrast extravasation ↪ occurred from the aneurysm. Several angioplasty principles were ignored: 1) PTA of a stenosis adjacent to an aneurysm increases rupture risk, 2) the balloon should not have been oversized to such a degree, and 3) a wire should have been left across the lesion until success is confirmed. Without guidewire access, a balloon could not be inflated for tamponade, and nephrectomy was necessary.*

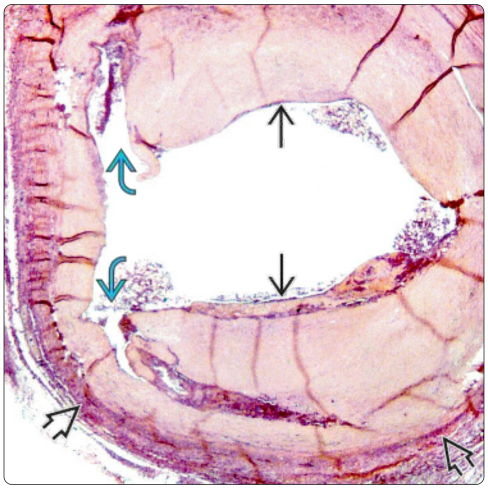


Complication of Angioplasty

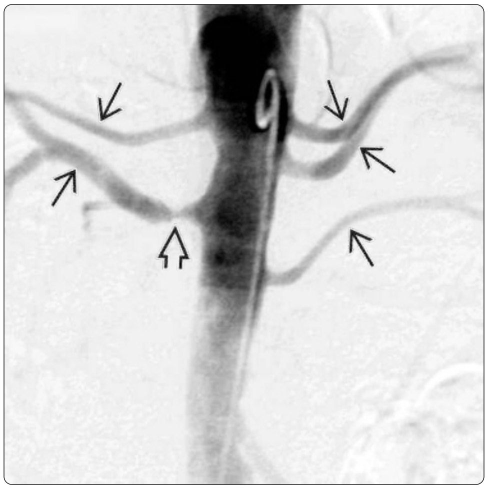


Complication of Angioplasty

Angioplasty Histologic Section

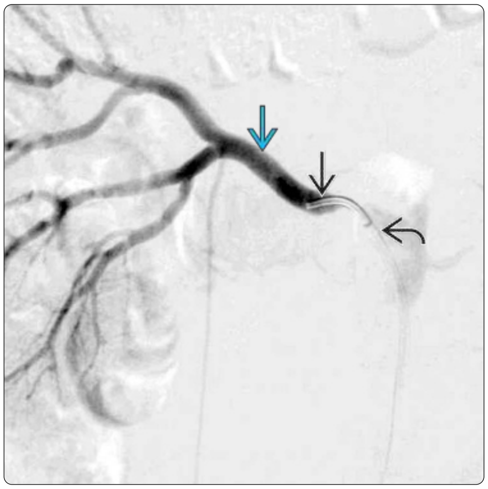


Coaxial Rapid-Exchange System (Diagnostic Aortogram)

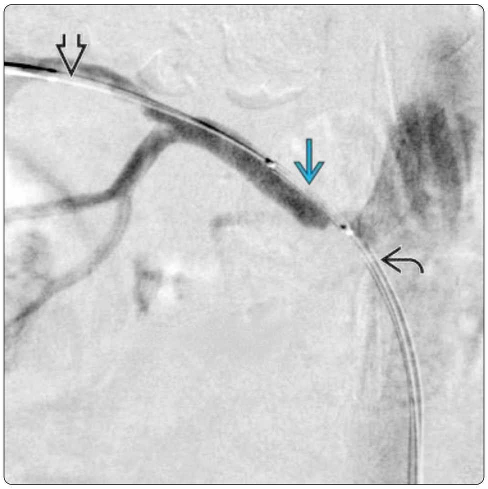


(Left) *Axial pathologic specimen from an artery following angioplasty shows the hyperplastic intima* → *with clefts* ↪ *caused by inflation of the angioplasty balloon. The muscular media* ⇨*, which is seen surrounding the intima, typically responds to angioplasty through stretching, not tearing, thereby preserving vascular integrity.* **(Right)** *Abdominal aortogram via a pigtail catheter reveals multiple renal arteries bilaterally* → *with a high-grade stenosis* ⇨ *in the dominant right renal artery.*

Coaxial Rapid-Exchange System (Selective Right Renal DSA)

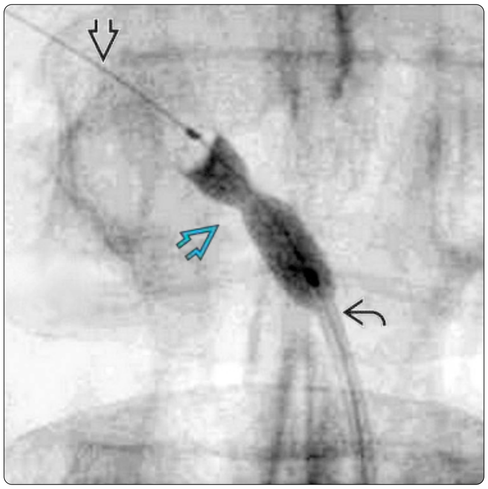


Coaxial Rapid-Exchange System (Positioning 0.014" Balloon)

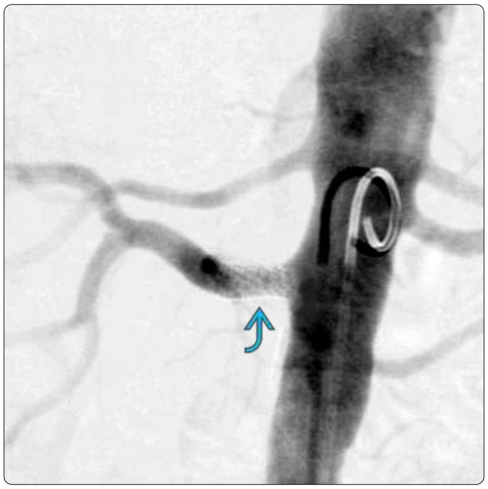


(Left) *A 4-Fr Cobra catheter* → *was coaxially introduced over an 0.035" guidewire (through a 5-Fr guiding catheter* ↪*) into the dominant right renal artery beyond the stenosis* →*. The 0.035" wire was removed and DSA was performed.* **(Right)** *An 0.014" guidewire* ⇨ *was introduced, the Cobra catheter was removed, & a rapid-exchange angioplasty balloon* → *was introduced coaxially through the guiding catheter* ↪*. Contrast injection through the guiding catheter shows that the balloon should be pulled back slightly to center on the stenosis.*

Coaxial Rapid-Exchange System (Angioplasty of Ostial Stenosis)



Coaxial Rapid-Exchange System (Suboptimal Result, Stent Deployed)



(Left) *During PTA, a "waist"* ⇨ *indents the balloon, confirming correct positioning. The guiding catheter tip* ↪ *buttresses the balloon to prevent movement into the aorta. The guidewire* ⇨ *remains in place.* **(Right)** *DSA via the guiding catheter revealed a suboptimal result to angioplasty, as often occurs with orificial renal artery stenoses. Subsequently, a balloon-expandable stent* ↪ *was deployed, which markedly improved flow. The 0.014" was not removed until after the stent was securely deployed.*

KEY FACTS

TERMINOLOGY

- **Atherectomy**: Physical removal of atherosclerotic plaque, typically by cutting, shaving, or abrading with catheter-based mechanical device
  - **Directional atherectomy**: Plaque excised by rotating cutting blade; excised plaque removed
  - **Rotational atherectomy**: High-speed 360° rotating device tip abrades plaque (microscopic particles)
  - **Orbital atherectomy**: Eccentrically mounted rotating crown
  - **Laser atheroablation**: Debulk in-stent restenosis & fibrous cap

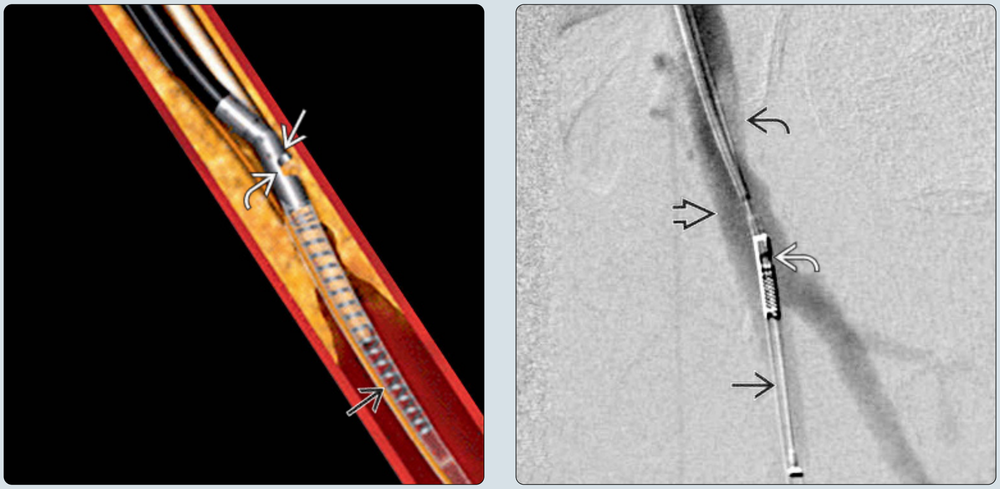
PROCEDURE

- Introduce vascular access sheath over guidewire
  - Fr size based on atherectomy device used
- Introduce diagnostic catheter, image inflow
- Selectively catheterize, image target & runoff
- Advance sheath upstream of stenosis
- Administer heparin prior to crossing lesion
- Advance guidewire/catheter across stenosis
- Exchange for 0.014" guidewire
- Consider placing embolic protection device (EPD)
- Introduce atherectomy device through sheath over guidewire; can inject sheath to show target lesion
- Perform atherectomy (device-specific usage)
- Obtain angiogram through sheath
  - Determine if additional atherectomy needed
- Remove embolic protection device/guidewire
- Perform completion angiogram with distal runoff

OUTCOMES

- **Complications**
  - Distal embolization: Avoid by using EPD
  - Arterial perforation: Overly aggressive atherectomy
- **Expected outcomes**
  - Plaque debulking can lead to decreased bail-out stenting
  - Intermediate & long term: Similar to angioplasty alone

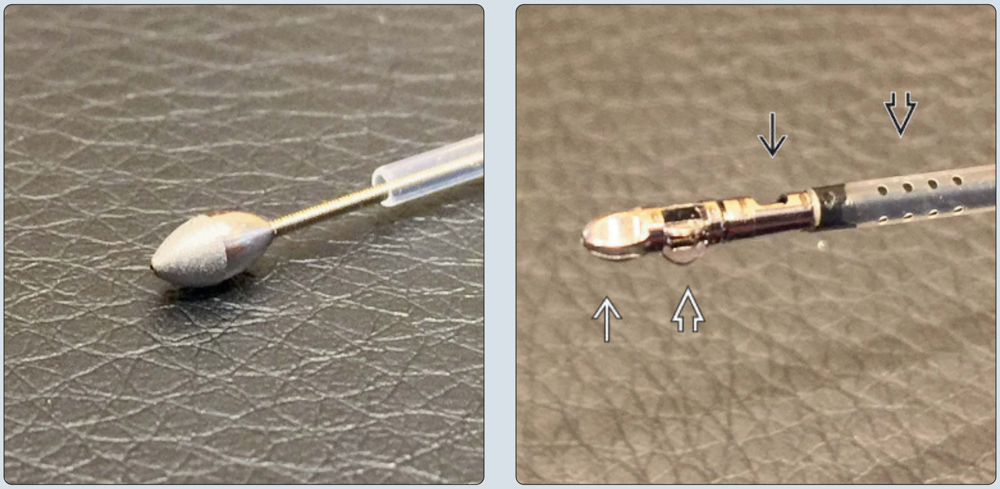
(Left) *Graphic shows the rotating blade ➡ & cutting window ⤷ of a directional atherectomy device. Excised atherosclerotic plaque is collected in a chamber → at the tip of the device.* **(Right)** *DSA shows the cutting window ⤷ of a directional atherectomy device in the common femoral artery ⇨. The nose cone →, used for collection of excised plaque, extends into the SFA. Eccentric plaque ↪ is present.*



Directional Atherectomy Device

Directional Atherectomy Device in Use

(Left) *The Peripheral Rotablator is an example of a rotational atherectomy device. Available at 1.25- to 2.5-mm diameter, it tracks over a 0.014" wire. Theoretically, the device pulverizes plaque as it spins, limiting the risk of occlusive distal emboli.* **(Right)** *The Jetstream atherectomy device removes excised debris via an aspiration port →, reducing the risk of embolization. Multiple smaller infusion ports ⇨ maintain a steady stream of fluid to allow aspiration. Front-cutting blades ➡ & expandable blades ⮕ debulk plaque.*



Rotational Atherectomy Device

Rotational Atherectomy With Continuous Infusion

TERMINOLOGY

Definitions

- **Atherectomy**: Physical removal of atherosclerotic plaque, typically by cutting, shaving, or abrading with catheter-based mechanical device
  - **Directional atherectomy**
    - Advantage of avoiding barotrauma
      - Reducing risk of dissection & intimal hyperplasia
    - Plaque excised by rotating cutting blade
    - Blade housed in cutting window on device
      - Bend in catheter apposes window against plaque
      - Window rotated/positioned against plaque
      - Blade excises only area that window exposes
    - Excised plaque collected in chamber at device tip
      - Device must be removed to empty chamber
    - SilverHawk/TurboHawk/HawkOne (Medtronic; Plymouth, MN)
      - 0.014" monorail guidewire compatible
      - Plaque excised is collected in tip variable capacity
      - HawkOne: 2- to 7-mm diameter vessel (consider below-knee)
      - TurboHawk: Variant for highly calcified lesions
  - **Rotational atherectomy**
    - High-speed 360° rotating device tip or burr
    - Preferentially abrades inelastic plaque
      - Microscopic nonobstructing particles enter arterial circulation
    - Phoenix (Volcano; San Diego, CA): 5-Fr, over-the-wire rotating blades pull debris into catheter, reducing risk of distal emboli
    - Jetstream (Boston Scientific; Marlborough, MA): Rotating cutting tip expands; continuous infusion & aspiration removes excised debris without removal of device; consider use with mixed calcified & thrombotic lesions
    - Peripheral Rotablator (Boston Scientific; Marlborough, MA): Rotating diamond-coated burr advanced via 4-Fr guide sheath
  - **Orbital atherectomy**
    - Eccentrically mounted rotating crown sands down plaque
    - Diamondback 360° (Cardiovascular Systems; St. Paul, MN): Rotating diamond-coated crown, 4-Fr device, used in arteries as small as 2 mm in diameter
  - **Laser atheroablation**
    - Excimer Laser System (Spectranetics; Colorado Springs, CO)
    - Can debulk in-stent restenosis & fibrous cap

PREPROCEDURE

Indications

- Focal calcified arterial stenosis
  - Typically ideal lesion for atherectomy
    - Stenosis location, degree of calcium, runoff status determinants of suitability
    - Other endovascular options (e.g., angioplasty) may also be appropriate treatment
- Lesions with characteristics unsuitable for other potential endovascular treatment options

Contraindications

- Lower extremity stenotic/occlusive peripheral arterial disease (PAD) with high thromboembolic risk
  - Acute thrombotic occlusion
  - Bulky, polypoid plaque; thrombus or embolus associated with lesion
- Extreme arterial tortuosity
- Chronic total occlusions that cannot be crossed
- Unapproved use outside of peripheral vasculature

Getting Started

- Things to check
  - Clinical history & physical examination
    - Emphasis on PAD risk factors
    - Detailed pulse examination/Doppler evaluation
    - Current medications
      - Any anticoagulants, antiplatelet agents, oral hypoglycemic agents, antihypertensives
- Medications
  - Heparin
    - Usually administered prior to crossing lesion
    - Various intraprocedural administration regimens
      - Bolus dose of 2,500-5,000 U; followed by infusion of 1,000 U/hr
      - Loading dose of 50-100 U/kg; followed by continuous infusion of 15-25 U/kg/hr
  - Vasodilator (e.g., nitroglycerin)
    - Typical bolus dose of 100 μg
    - Prevents/treats catheter-induced vasospasm
  - Clopidogrel
    - May electively give loading dose preprocedure
      - 300 mg minimum loading dose
    - Continue maintenance dose post procedure
      - 75 mg daily dose for 4-6 weeks minimum

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Patient usually supine
  - Common femoral artery access
    - Retrograde vs. antegrade access
      - Retrograde common femoral artery access for pelvic, contralateral lower extremity lesions
      - Antegrade common femoral artery access may be used for ipsilateral lower extremity lesions

Procedure Steps

- **General**
  - Obtain vascular access
  - Introduce vascular access sheath over guidewire
    - Appropriate Fr size for atherectomy device
  - Introduce appropriate diagnostic catheter via sheath
    - Obtain diagnostic arteriogram; evaluate lesion
  - Exchange for selective catheter if necessary, selectively catheterize target artery
  - Position catheter proximal to target stenosis
  - Administer heparin bolus prior to crossing lesion
    - 2,500-5,000 U bolus (IV or IA)
  - Gently advance guidewire across stenosis
    - Imperative to avoid vessel dissection

- If resistance to guidewire passage
  - **Do not** keep advancing guidewire; may dissect
  - Retract wire, reorient catheter, readvance wire
  - Consider different catheter shape, guidewire
- Keep catheter parallel to vessel centerline
  - Must direct guidewire through central channel of stenosis, even if quite eccentric
- Advance selective catheter over wire, across lesion
- Exchange crossing guidewire for 0.014" guidewire
- Deploy of embolic protection device (EPD) is optional
- Introduce atherectomy device over guidewire
- Perform atherectomy
  - Inject sheath, evaluate atherectomy progress
  - If device removed, maintain guidewire access across lesion; obviates need to recross lesion
- Inject contrast through sheath at procedure end
  - Document atherectomy results
  - Determine if further intervention needed
- If satisfactory result, carefully withdraw guidewire
  - If EPD used, recapture/remove device
- Obtain completion arteriogram
  - Document runoff, final atherectomy results
- Remove access sheath, close arteriotomy site
  - Manually compress puncture site
  - May use closure device

- **Directional atherectomy**
  - Use appropriate sheath size for SilverHawk/TurboHawk device
    - Rapid-exchange (monorail) design
      - Device requires 0.014" guidewire
  - SpiderFX (ev3) EPD often concurrently used
  - Position device immediately proximal to lesion
  - Orient cutting window/blade against atheroma
  - Activate hand motor drive (engages cutting blade)
  - Steadily advance device through lesion
    - Never withdraw device with cutting blade active
      - Could shear off atheroma, embolize distally
  - Deactivate motor, reposition device above lesion
    - Turning motor off compresses atheroma inside nose cone collection chamber
  - Orient cutting blade against different part of lesion
  - Repeat above process
    - Perform circumferential atherectomy
  - Periodically inject sheath, check progress
  - Remove device to empty atheroma from nose cone
    - Leave guidewire in place across lesion
      - Permits further atherectomy as necessary
  - Document final result angiographically
- **Rotational atherectomy**
  - **Jetstream**
    - Requires 7-Fr access sheath
    - Indicated in peripheral arteries ≥ 3 mm
    - Effective for both thrombus/calcium
    - Over-the-wire device requiring 0.014" guidewire
    - 3 components to device
      - Catheter with expandable cutting tip, aspiration/infusion capabilities
      - Control pod with keypad for device operation
      - Console device controller with power supply, peristaltic pumps for aspiration/infusion
    - Rotating cutting tip expands from 2.1 to 3 mm
    - Aspiration port collects thrombus/plaque while cutting tip is advanced through lesion
      - Plaque debulked, lumen enlarged
      - Followed by angioplasty/stenting as necessary
- **Orbital atherectomy**
  - **Diamondback 360° PAD system**
    - Requires 4-Fr access sheath
    - Crown orbits while advancing through lesion
      - Diamond-coated crown sizes: 1.25-2.25 mm
      - Can increase lumen diameter 2x
    - Crown abrades plaque; elastic nondiseased compliant tissue displaced, remains intact
    - Powered by variable-speed pneumatic drive
    - Place proprietary 0.014" ViperWire across lesion
    - Introduce device over wire; activate device
    - Plaque debulked as crown advanced back & forth through lesion
      - Orbiting circumference increases with speed
    - Abraded microscopic particles enter circulation
      - Average particle size 1.96 μm

Alternative Procedures/Therapies

- Radiologic
  - Angioplasty, stenting
- Surgical
  - Vascular bypass conduit, endarterectomy

OUTCOMES

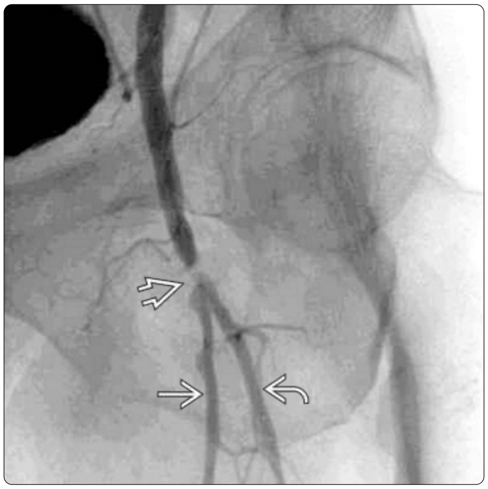
Complications

- Most feared complication(s)
  - Distal embolization of atheroma (~ 3%)
    - Avoid by using embolic protection device
  - Arterial perforation
    - Can occur with overly aggressive plaque removal
      - Deep cutting/abrading can violate media
      - Avoid by debulking only until luminal improvement equals normal vessel diameter
- Immediate/periprocedural complication(s)
  - Hematoma
    - Atherectomy device requires larger access sheath
  - Arterial thrombosis
    - Heparinize during atherectomy; decreases risk
- Delayed complication(s)
  - Pseudoaneurysm/arteriovenous fistula

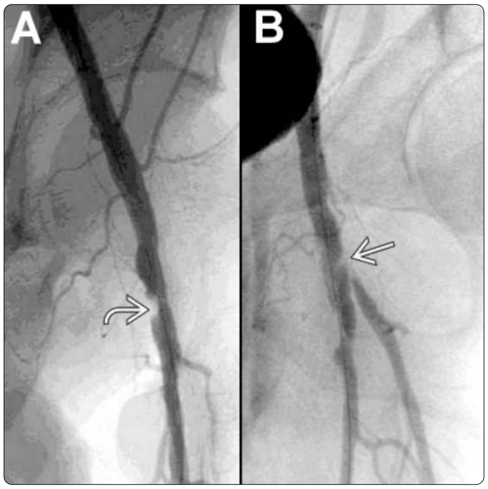
Expected Outcomes

- Registries/single-center data show high initial technical success (≥ 95%), decreased need for bail-out stenting, low complication rates, allowing atherectomy consideration in cases of chronic limb ischemia
- Intermediate & long-term results do not seem to show improved clinical outcomes over angioplasty alone
- Significantly increases procedural cost/time & radiation
- No efficacy/safety studies comparing atherectomy devices
- Trials comparing atherectomy + drug-eluting balloons currently ongoing

Directional Atherectomy (Anteroposterior View)

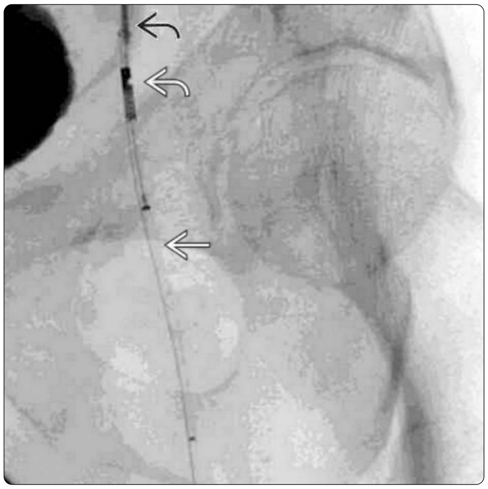


Directional Atherectomy (Oblique View)

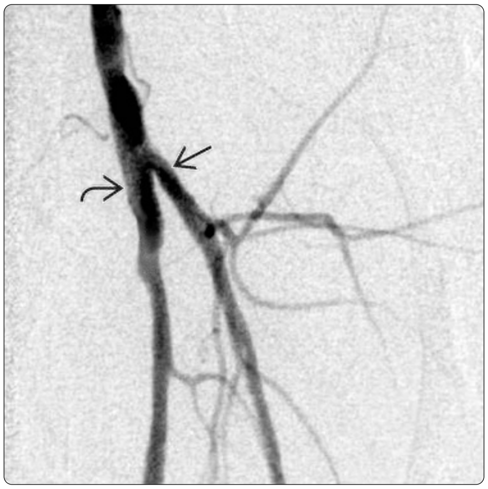


(Left) *Angiography shows a high-grade stenosis ⇨ in the distal common femoral artery at the level of the bifurcation into the superficial → & profunda femoral ↪ arteries.* **(Right)** *(A) The eccentric stenosis at the SFA origin ↪ is best seen in RAO, & (B) the high-grade profunda femoral artery origin stenosis → is best seen in LAO. This is a difficult lesion for either angioplasty or stenting because of the 2 adjacent arterial origins. Surgical endarterectomy or atherectomy is a better treatment option.*

Directional Atherectomy (Device Visualization)

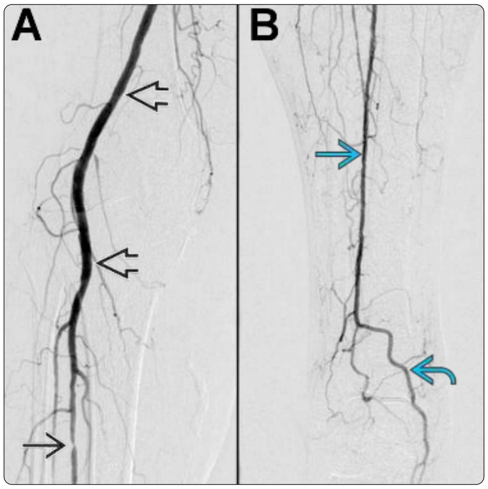


Directional Atherectomy (Post Atherectomy)

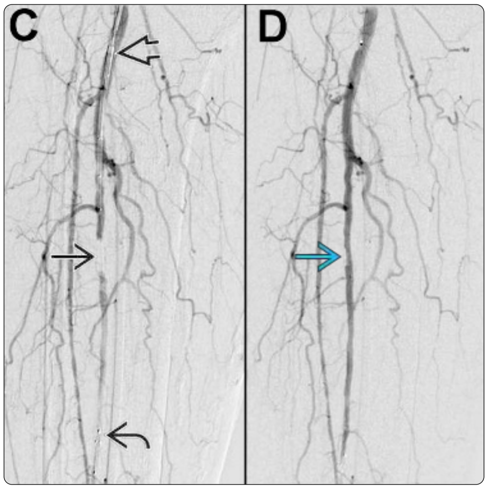


(Left) *A SilverHawk atherectomy device has been positioned in the common femoral artery by advancing through a guiding sheath ↪ over a 0.014" guidewire. The cutting window ↪ is located in the proximal part of the device, & the collection chamber for excised atheroma is distal →.* **(Right)** *Following plaque excision with the directional atherectomy device, the superficial femoral ↪ & profunda femoral → arteries are widely patent, as are all branch vessels.*

Infrapopliteal Atherectomy (Initial DSA)

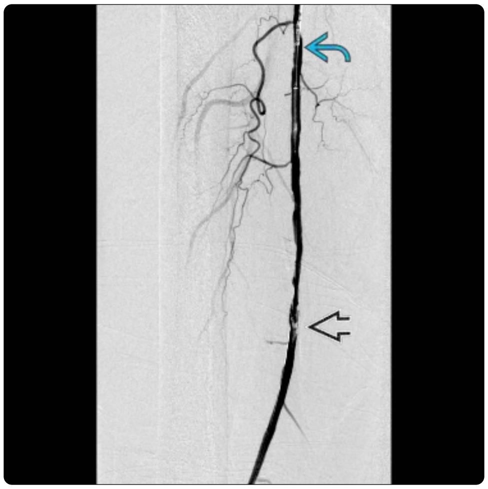


Infrapopliteal Atherectomy (Post Atherectomy)

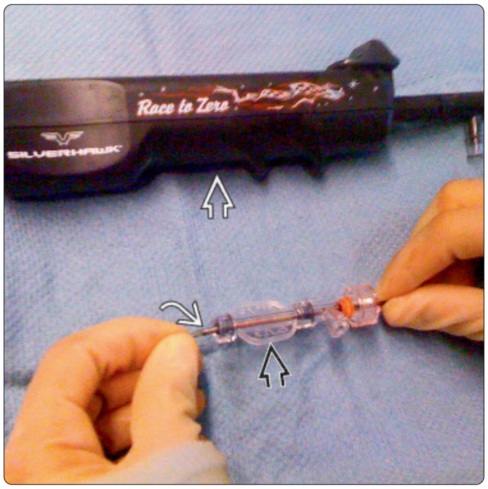


(Left) *DSA of the right leg in a patient with a nonhealing foot ulcer shows (A) an unremarkable popliteal artery ⇨ but a high-grade stenosis → in the peroneal artery. Distally (B), the peroneal artery → is the sole runoff vessel to the foot & forms the plantar arch ↪.* **(Right)** *DSA during atherectomy shows (C) an embolic protection device ↪ distal to the peroneal lesion →. An atherectomy device ⇨ is in the popliteal artery. (D) After atherectomy, there is only minimal residual irregularity → at the prior lesion site.*

(Left) *DSA shows a severe SFA stenosis ⇨ with an extremely irregular appearance. Given the angiographic appearance of the stenosis & a clinical history consistent with distal embolization, a distal embolic protection device was used during atherectomy. Directional atherectomy catheter ⤻ is in the proximal SFA.* **(Right)** *Hand-held battery-powered drive unit ➡ & tip ⤻ of the atherectomy device are shown. The atherectomy tip is inside of a flushing tool ⇨ designed to remove the excised atheroma from the collection chamber.*

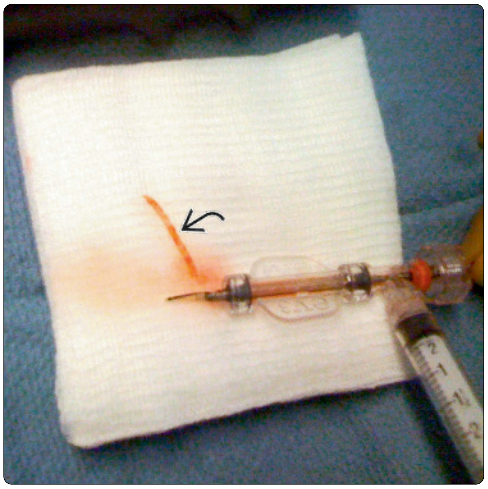


Atherectomy With Embolic Protection (Initial DSA)

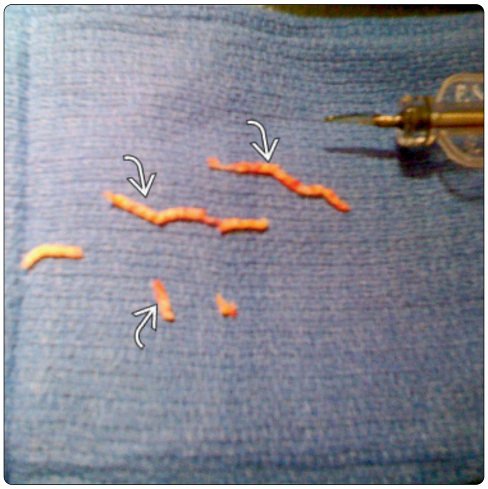


Atherectomy With Embolic Protection (Atherectomy Device)

(Left) *Flushing the distal collection chamber of the atherectomy device clears away a large core of excised atheroma ⤻. As the cutting blade excises atheroma, the plaque is collected & compressed in the collection chamber. After multiple passes through the lesion, the device must be removed & the chamber emptied.* **(Right)** *Photograph shows the atheromata ⤻ that were excised. Atherectomy debulks plaque from the artery, with a result that is analogous to surgical endarterectomy.*

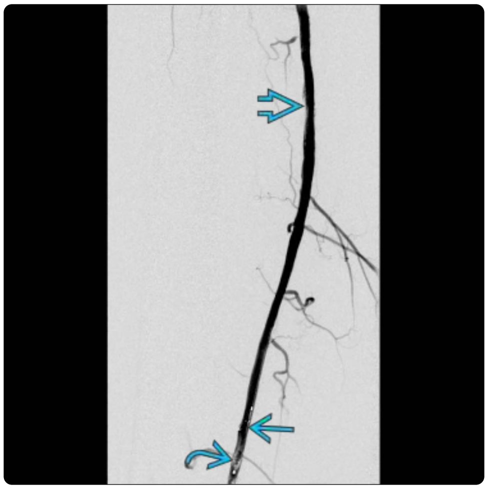


Atherectomy With Embolic Protection (Evacuation of Collection Chamber)

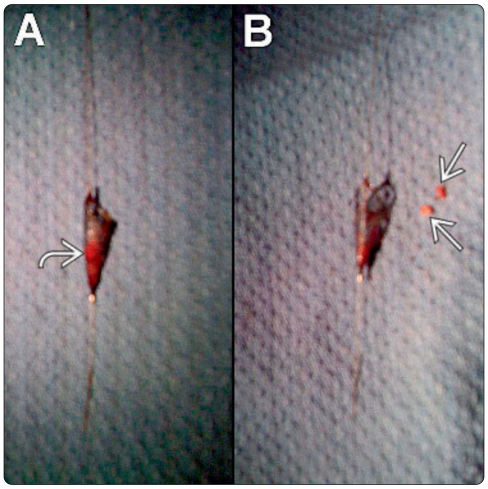


Atherectomy With Embolic Protection (Excised Cores)

(Left) *After atherectomy, only minimal irregularity ⇨ remains at the site of the lesion. The SpiderFX embolic protection device ⇨ can be seen distal to the lesion. There is a filling defect ⤻ in the distal portion of the device, consistent with trapped embolic debris.* **(Right)** *Photographs show: (A) macroscopic debris ⤻ distally in the embolic protection device, which correlates with the angiographic findings; (B) 2 discrete rock-like atheromatous fragments ➡ were removed from the protection device.*

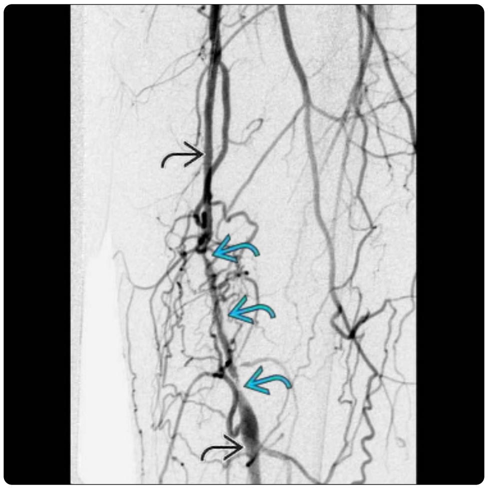


Atherectomy With Embolic Protection (Post Atherectomy)

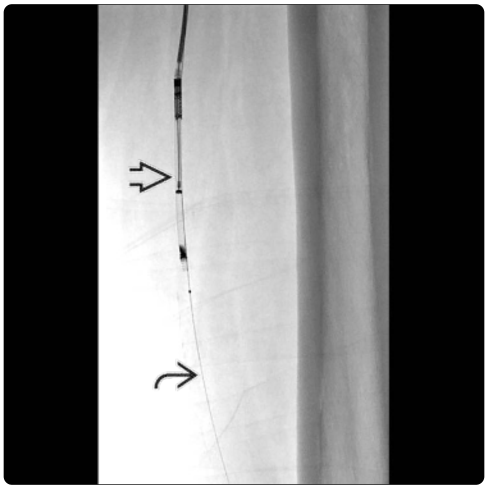


Atherectomy With Embolic Protection (Embolic Protection Device)

Complication of Atherectomy (Initial DSA)

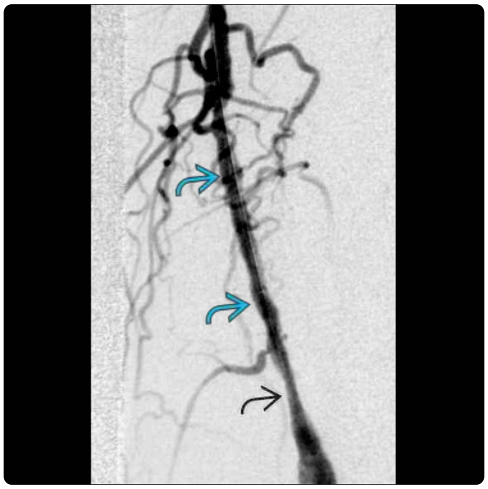


Complication of Atherectomy (Directional Atherectomy Device)

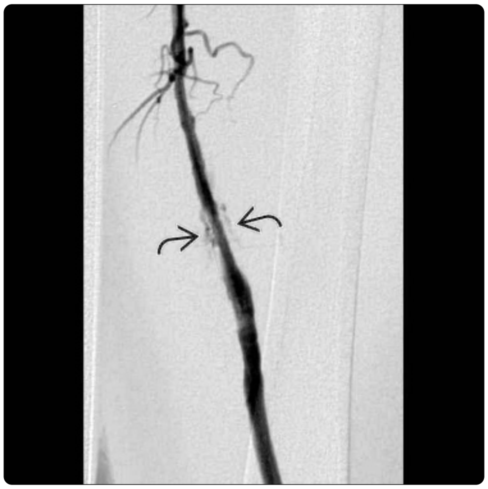


(Left) *Magnified DSA of the distal left SFA shows a severe stenosis* ↪ *(& multiple collaterals) with a normal-caliber adjacent arterial segments* ↪*. Unsubtracted views showed that the lesion was heavily calcified.* **(Right)** *Fluoroscopic spot radiograph shows that a guidewire* ↪ *has been advanced through the stenosis & a TurboHawk atherectomy device* ⇨ *has been introduced & positioned proximal to the lesion. This directional atherectomy device is designed for plaque excision in calcified lesions.*

Complication of Atherectomy (Initial Postatherectomy Result)

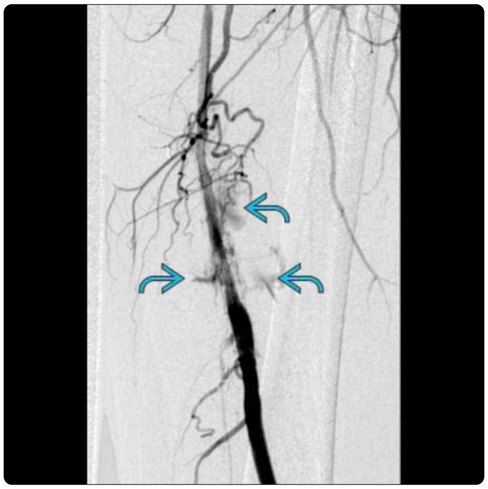


Complication of Atherectomy (Arterial Perforation, Early Image)

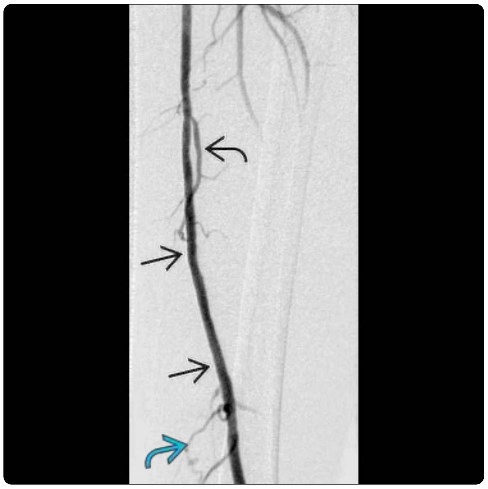


(Left) *DSA of the target lesion following initial atherectomy shows a marked improvement to the luminal caliber* ↪ *with some degree of residual stenosis distally* ↪*. It was elected to further debulk the distal area of residual stenosis with additional atherectomy.* **(Right)** *Following additional atherectomy, there is satisfactory luminal caliber throughout the treated SFA segment. However, new linear contrast collections* ↪ *parallel the arterial lumen at the distal treatment zone.*

Complication of Atherectomy (Arterial Perforation, Delayed Image)



Complication of Atherectomy (Covered Stent Deployment)



(Left) *Delayed image shows contrast extravasation* ↪ *arising from the distal treatment zone, indicating a breach to the arterial integrity at this level. Arterial perforations or arteriovenous fistulas can occur with overly aggressive plaque removal, which violates the media.* **(Right)** *A covered stent was placed along the entire length of the atherectomy treatment zone* →*, preserving collaterals proximally* ↪ *& distally* ↪*. Covered stent placement eliminated the extravasation & restored vascular integrity.*

Thrombolysis

KEY FACTS

TERMINOLOGY

- **Thrombolysis**: Minimally invasive method for clearing/dissolving intravascular thrombus
    - Intravenous thrombolysis delivers systemic dose of medication designed to promote fibrinolysis
    - Intravascular thrombolysis requires placement of catheter/device into thrombosed vessel
        - **Catheter-directed thrombolysis (CDT)**: Infusion of thrombolytic agent via percutaneously placed catheter
        - **Mechanical thrombolysis (MT)**: Fragmentation of thrombus using intravascular medical device
        - **Pharmacomechanical thrombolysis (PMT)**: Use of combined mechanical device/thrombolytic agent

PREPROCEDURE

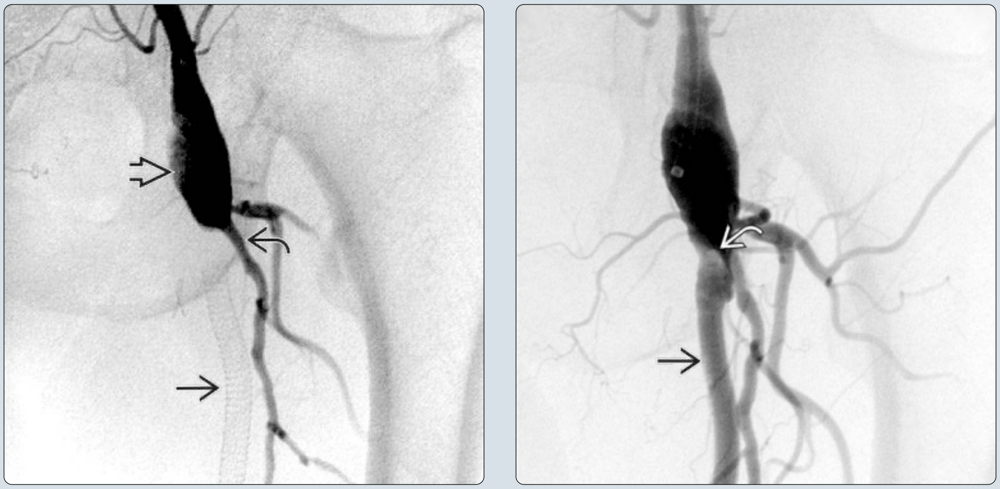
- Indication: Symptomatic acute/subacute, arterial/venous thrombosis
- Absolute contraindications
    - Active bleeding/uncorrectable coagulopathy
    - Aortic dissection
    - History of hemorrhagic/recent ischemic stroke
    - Recent head trauma/intracranial surgery/neoplasm

PROCEDURE

- Perform DSA via access sheath or catheter
- Pass catheter/guidewire through occlusion
- Initiate desired thrombolytic therapy
- ICU monitoring during thrombolysis infusion
    - Check fibrinogen/PTT/CBC values q 6-8 hours
- DSA to reassess thrombus burden within 8-20 hours

OUTCOMES

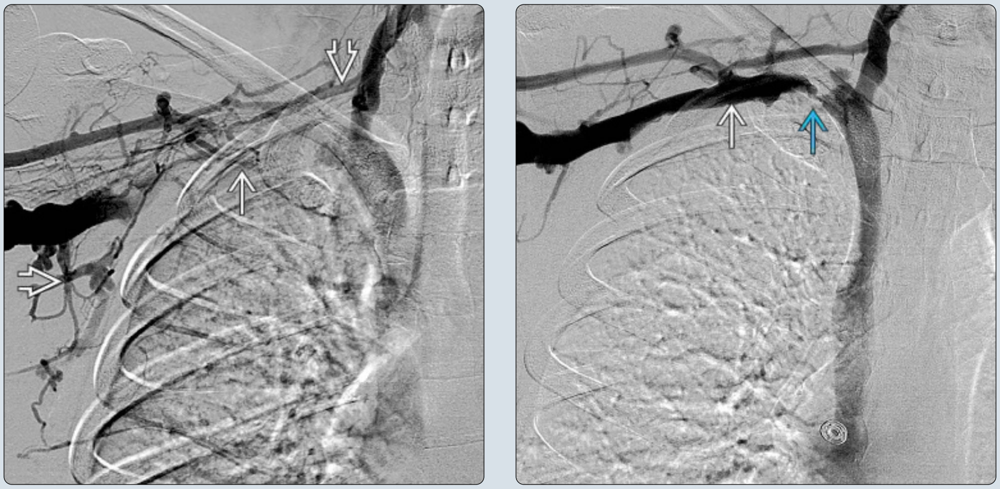
- Complications: Hemorrhage, distal emboli (extremities), pulmonary embolism, reperfusion syndrome
- Expected outcomes: Symptomatic improvement following successful thrombolysis



Arterial Bypass Graft Prethrombolysis

Arterial Bypass Graft Postthrombolysis

(Left) *Femoral DSA shows the proximal anastomotic hood ⇨ of a femoropopliteal bypass graft, filling only the profunda femoral artery ↶, consistent with graft thrombosis. A previously placed stent → can be seen within the thrombosed graft.* **(Right)** *DSA after intraarterial thrombolysis shows a patent bypass graft →. A filling defect ➡ near the graft hood may be the cause of thrombosis. Any underlying abnormality such as this should be corrected to prevent recurrent thrombosis.*



Venous Thrombosis (Prethrombolysis)

Venous Thrombosis (Postthrombolysis)

(Left) *Right upper extremity DSA in a case of primary axillosubclavian vein thrombosis reveals occlusive thrombus within the axillary and subclavian veins ➡, with associated collateral venous enlargement ➡ returning venous drainage.* **(Right)** *Following CDT, no thrombus remains and flow is restored within the axillary and subclavian veins ➡. However, high-grade stenosis is revealed ⇨. Additional subsequent therapies (in this case surgical release, then angioplasty) are often necessary following thrombolysis.*

TERMINOLOGY

Definitions

- **Thrombolysis**: Minimally invasive method for clearing/dissolving intravascular thrombus
  - Intravenous (IV) thrombolysis delivers systemic dose of medication designed to promote fibrinolysis
    - Most commonly used form of thrombolysis
      - Tissue plasminogen activator (tPA) most frequently used thrombolytic drug
  - Direct intravascular thrombolysis requires placement of catheter/device into thrombosed vessel
    - May place either intraarterially or intravenously
      - Localized treatment of thrombosed target vessel
- **Thrombolytic agent**: Thrombus-dissolving medication
  - tPA
    - Catalyzes plasminogen conversion into plasmin
    - 5 min half-life; high fibrin specificity
    - Recombinant tPA (r-tPA) also available; made using recombinant biotechnology; various proprietary brands
      - Activase (alteplase) (Genentech)
      - Retavase (reteplase) (EKR Therapeutics)
      - TNKase (tenecteplase) (Genentech)
  - Streptokinase
    - Indirect plasminogen activator
    - Unpopular due to antigenicity: Inactivated by antibody formation
  - Urokinase
    - Induces systemic lysis; poor fibrin sensitivity
    - Metabolized in liver; 15 min half-life
- **Catheter-directed thrombolysis (CDT)**: Infusion of thrombolytic agent via percutaneously placed catheter
  - Also termed pharmacologic thrombolysis
    - May be intraarterial or intravenous
      - Delivers concentrated dose to thrombosed vessel
- **Mechanical thrombolysis (MT)**: Fragmentation of thrombus using intravascular medical device
  - Macerates clot into macro-/microscopic debris
- **Pharmacomechanical thrombolysis (PMT)**: Use of combined mechanical device/thrombolytic agent
  - Increases thrombus surface area in contact with thrombolytic
  - Combined therapy typically more effective

Clinical Vascular Thromboembolic Scenarios

- **Acute limb-threatening ischemia (ALI)**
  - Sudden decrease in arterial perfusion to limb, potentially threatening its viability
    - Capillary return/pulses/sensation may be compromised/absent
      - Check for 5 Ps: Pain, pallor, pulselessness, paralysis, paresthesia
    - Causes of acute limb-threatening ischemia
      - Arterial embolus from proximal source
      - Arterial disruption/trauma
      - Acute in situ arterial thrombosis
- **Acute mesenteric ischemia**
  - Arterial occlusive form may be embolic or thrombotic; venous form is thrombotic
- **Portal venous thrombosis**
  - Primary form: Idiopathic
  - Secondary: Known etiologic factor
    - e.g., prothrombotic state/neoplasm/inflammatory
- **Pulmonary embolism (PE)**
  - Massive pulmonary embolism with right heart strain
- **Lower extremity venous thrombosis**
  - **Phlegmasia cerulea dolens**: Severe form of deep venous thrombosis (DVT); thrombotic occlusion of entire venous drainage of extremity
    - Acute, severe pain; cyanosis and edema
    - 40-60% result in venous gangrene; 20-50% amputation
    - Underlying malignancy in 50% of cases
  - **Postthrombotic syndrome (PTS)**: DVT sequela
    - Result of chronic venous hypertension
      - Due to valvular damage, venous reflux, impaired venous return
    - Aggressively treat DVT to limit PTS risk
      - 20-40% of iliofemoral DVT develop PTS in 2 years
- **Upper extremity venous thrombosis**
  - **Axillosubclavian vein thrombosis (ASVT)**
    - Primary form: Paget-Schroetter syndrome
    - Secondary form: Associated inciting venous injury
      - Long-term central venous catheters/pacemakers
      - Malignancy/adenopathy

PREPROCEDURE

Indications

- Symptomatic acute or subacute arterial or venous thrombosis
  - Chronic thrombosis: Poor recanalization success rates

Contraindications

- Absolute contraindications
  - Active bleeding/uncorrectable coagulopathy
  - Aortic dissection
  - History of hemorrhagic/recent ischemic stroke
  - Recent head trauma/intracranial surgery (< 3 months)
  - Intracranial neoplasm
- Major relative contraindications
  - Remote ischemic stroke (> 3 months)
  - Recent major thoracic/abdominal surgery (≤ 3 weeks)
  - Recent major trauma (≤ 4 weeks)
  - Recent gastrointestinal hemorrhage (≤ 3 months)
  - Prolonged or traumatic CPR (> 10 min)
  - Uncontrolled hypertension
  - Allergy to angiographic contrast media
- Minor relative contraindications
  - Pregnancy
  - Renal or hepatic insufficiency (bleeding risk)

Preprocedure Imaging

- **US**
  - High sensitivity/specificity for DVT
    - Use compression/color Doppler techniques
    - Iliocaval involvement poorly assessed with US
  - Highly sensitive/specific for arterial occlusion
    - Evaluates inflow to diseased segment
    - Poorly assesses aortoiliac involvement/extent

- **CTA/CTV**
  - Excellent for aortoiliac/iliocaval evaluation
  - Shows thrombus extent, anatomic abnormalities
  - Highly sensitive/specific for IVC/pelvic/femoropopliteal DVT
  - Highly sensitive for aortic/pelvic/femoropopliteal arterial occlusion
    - Less specific for etiology of arterial occlusion
- **MRA/MRV**
  - Good vascular anatomic display
  - Highly sensitive/specific for thrombosis
    - Can differentiate acute vs. chronic

Getting Started

- Things to check
  - Check bleeding/coagulation parameters
    - Correct any coagulopathy prior to procedure
      - Minimizes risk of bleeding complications
  - Attempt to determine underlying cause of thrombosis
    - Underlying hypercoagulability/coagulopathy
  - Review imaging findings/identify involved vessels
    - Access site should avoid thrombus margin
      - Allows for complete guidewire/catheter traversal
  - Assess renal function
    - Prefer eGFR > 60
  - Arrange ICU admission (continuous thrombolysis)
    - Ensure nursing staff familiar with thrombolysis regimen, equipment, bleeding complications monitoring
  - Baseline assessment of distal pulses/neurologic status
- Medications
  - Heparin
  - Thrombolytic agent
  - Lidocaine 1-2% (local anesthetic)
- Equipment list
  - **Infusion pump**: Ensure pump-pressure sufficiently high to deliver thrombolytics through infusion catheter
  - **Infusion catheters**: Typically have multiple sideholes/slits; various catheter/infusion lengths
    - Proprietary therapeutic infusion systems
      - UniFuse infusion catheter (AngioDynamics)
      - SpeedLyser infusion system (AngioDynamics)
      - Cragg-McNamara valved infusion catheter (ev3)
      - ProStream infusion wire (ev3)
      - MicroMewi multiple sidehole infusion catheter/microcatheter (ev3)
      - Fountain infusion system (Merit Medical)
      - Mistique infusion catheter (Merit Medical)
    - Pulse*Spray infusion catheter (AngioDynamics): Allows rapid administration of fibrinolytics into thrombus via hand injection
    - EkoSonic endovascular system (Ekos): US-accelerated thrombolysis infusion catheter
      - High-frequency, low-energy US core inside multiple sidehole infusion catheter
      - US relaxes fibrin strands; exposure of more surface area for fibrinolysis
  - **Mechanical thrombectomy devices**: Examples of devices achieving thrombolysis through clot fragmentation/aspiration
    - Indigo (Penumbra); separator-assisted aspiration
      - Penumbra; separator-assisted aspiration, for intracranial use in acute stroke
    - AngioJet rheolytic system (Medrad); retrograde fluid jet pulls thrombus into catheter via Bernoulli effect, where it is macerated
    - AngioVac Cannula & Circuit (AngioDynamics); high-flow aspiration via extracorporeal bypass circuit
    - Cleaner rotational thrombectomy system (Argon Medical); direct contact fragments thrombus
    - Arrow-Trerotola PTD (Teleflex Medical); direct contact fragments thrombus
    - Aspirex S (Straub Medical AG); rotating spiral creates negative pressure pulling thrombus into catheter (use in veins, arteries, dialysis access)
      - Rotarex S (Straub Medical AG); rotating spiral creates high negative pressure (possibly too high for venous use) pulling thrombus into catheter

PROCEDURE

Procedure Steps

- **Introduction of thrombolysis/thrombectomy device**
  - Consider placing Foley catheter prior to procedure
  - Arterial treatment: Contralateral femoral artery access often preferred
    - Minimizes need for 2nd puncture/conversion from retrograde to antegrade access
    - Ipsilateral antegrade puncture useful for below-knee occlusions
  - Venous treatment
    - Consider IVC filter placement: Protects against life-threatening iliofemoral thrombotic embolus, can introduce from internal jugular access (avoiding traversal of thrombus) and potentially removed after completion of procedure
  - Sterilely prepare/drape intended access point
  - Initiate sedation as needed
  - Obtain vascular access
    - May use US guidance to minimize number of puncture attempts, limiting bleeding risk during thrombolysis
    - Single-wall access technique preferred; Double-wall puncture increases bleeding risk
  - Place vascular access sheath (usually ≥ 6 Fr)
    - Should be at least 1 Fr size larger than thrombolysis catheter/device
    - Permits concomitant heparin infusion
    - Allows for blood sampling during thrombolysis
  - Perform DSA via access sheath/introducer
    - Extensive collaterals suggest chronic lesion, which may not be amenable to thrombolysis
  - Advance catheter & hydrophilic wire (e.g., Glidewire, Roadrunner) through thrombus
    - If cannot pass wire
      - Advance catheter and wire in incremental 1- to 2-cm intervals
      - Consider using specialized 3- to 4-Fr smooth-tip catheters
      - Consider use of coaxial guidecatheter, a longer sheath which can reach thrombus

      - Reattempt after short (2-4 hours) thrombolytic infusion at thrombus margin
      - Poor thrombolysis candidate if unable to pass guidewire
  - Once catheter beyond thrombus, inject contrast to confirm catheter is intraluminal
  - Exchange hydrophilic to nonhydrophilic wire (e.g., Bentson, Rosen, Amplatz)
  - **Mechanical thrombectomy**
    - **Caution:** Administer IV heparin bolus prior to treatment; mechanical fragmentation of thrombus can result in life-threatening pulmonary emboli; endoluminal treatment can resultant new thrombus formation
    - Consider starting with simple aspiration: Advance catheter tip (or 8- 10-Fr sheath) into thrombus and aspirate
    - Pharmacomechanical thrombolysis: Consider delivery of thrombolytic agents (e.g., 2-10 mg tPA) through mechanical thrombectomy devices during use, or through catheter into thrombus immediately prior to mechanical thrombectomy
    - May be performed in single-setting, or as 2-part procedure
      - Initial mechanical thrombectomy may "debulk" thrombus; can follow with CDT
      - Inadequate single-setting treatment may be converted to CDT
    - May consider using embolic protection device (EPD) distal to thrombosed segment
      - Depends on thrombus location, appropriate "landing zone" for EPD
      - Consider IVC filter for large iliofemoral thrombus
    - Maceration of thrombus (typically venous) may be performed with angioplasty balloons: Goal of restoring intraluminal flow
    - Trapping thrombus (typically arterial) may be performed with placement of covered stent: Goal of restoring intraluminal flow while preventing embolic phenomena
    - Reassess with DSA following thrombectomy
      - If no/trace residual thrombosis, no further endovascular intervention required; start/continue systemic anticoagulation
      - If significant residual thrombus (and acceptable bleeding parameters), consider alternate mechanical thrombectomy device or CDT
      - If no angiographic improvement & signs of chronicity, consider terminating procedure
- **Initiation of thrombolysis/thrombectomy**: Consider mechanical thrombectomy vs. catheter-directed thrombolysis thrombolysis
  - **Catheter-directed thrombolysis**
    - Place thrombolysis catheter over guidewire
      - Catheter infusion-length should extend proximal and distal to thrombus
      - Multiple, sidehole catheter evenly distributes thrombolytic agent
    - Initiate continuous infusion of thrombolytic via multiple-sidehole catheter
      - Alteplase 0.5-1.0 mg/h
      - Reteplase 0.5-1.0 U/h
      - Tenecteplase 0.25-0.5 mg/h
      - Urokinase 60,000-240,000 U/h
  - Initiate continuous infusion of heparin via side arm of introducer sheath or peripheral IV
    - Initial heparin bolus of 2,000-5,000 units followed by low-dose infusion at 100-500 U/h
  - Admit for observation during thrombolytic infusion
    - ICU stay often necessary (follow hospital protocol)
    - Check fibrinogen, PTT (anti-Xa), CBC every 6-8 hours
      - If fibrinogen < 100 mg/dL or PTT > 60 seconds, hold thrombolytics; replace thrombolytic with normal saline running through catheter at same rate
      - If fibrinogen < 150 mg/dL or decreased > 50% since last lab, decrease lytic rate by 1/2 (thereby reducing dose)
    - At least hourly monitoring
      - Assess for occult hemorrhage (e.g., intracranial/gastrointestinal bleeding, hematuria)
      - Check catheter insertion site for hematoma/bleeding or line disconnection
      - Check distal pulses for signs of embolism
    - Analgesia as needed to address pain
      - Arterial revascularization can be extremely painful
    - Discuss instruction/expectations with patient's nursing staff
      - Request contact proceduralist (not house staff) with concerns
      - Strict bedrest
      - NPO 8 hours prior to planned repeat angiogram
  - Follow-up results of thrombolysis within 8-20 hours
    - Minimum of 8-hour infusion usually required to achieve significant clearing
    - Patient should (most cases) return for DSA
  - Following infusion catheter removal, obtain DSA via introducer sheath; assess thrombolysis efficacy
    - If no/trace residual thrombosis, no further endovascular intervention required; start/continue systemic anticoagulation
    - If significant residual thrombus (and acceptable bleeding parameters), restart thrombolytic infusion with continued observation or consider mechanical thrombectomy
    - If no clinical/angiographic improvement & signs of chronicity, consider terminating procedure
  - **Postthrombectomy/thrombolysis**
    - If underlying stenosis identified, perform angioplasty followed by completion DSA
      - If postangioplasty DSA reveals residual stenosis/poor result, consider stent placement
      - Stent placement also commonly performed to correct May-Thurner anatomy
    - If satisfactory thrombolysis result and no underlying abnormalities
      - Remove indwelling catheters and sheath
      - May consider reversing anticoagulation before sheath removal
      - For arterial access, may use closure device
      - If IVC filter placed prophylactically, may remove filter upon completion of thrombolysis

Findings and Reporting

- Identify vessels involved; extent of baseline occlusion
- Provide medication/thrombolytic agent doses used
- Describe thrombolysis results
- Anticoagulation recommendations; clinical follow-up

Alternative Procedures/Therapies

- Surgical
  - Open surgical thrombectomy
- Other
  - Systemic thrombolysis
    - Increased risk of major bleeding complications

POST PROCEDURE

Things to Do

- Check distal pulses; compare against baseline
- If worsened perfusion or declining neurologic/pulmonary function, suspect distal embolism
  - Comparison with baseline imaging if available
  - During lower extremity arterial thrombolysis, may have initial worsening of ischemic symptoms
    - Partially lysed thrombus may embolize, occlude distal runoff
    - Depending upon severity, may require cessation of thrombolysis/surgical thrombectomy/bypass
- Evaluate further or follow-up for vascular lesions (e.g., stenosis) that may be contributing to thrombosis
- Update referring/consulting physicians during CDT
- After thrombolysis, initiate/resume anticoagulation
- If stent(s) placed, recommend Plavix 75 mg for 6 weeks
- May perform periodic noninvasive imaging surveillance for detection of restenosis

OUTCOMES

Complications

- Most feared complication(s)
  - Hemorrhage (stroke, intraabdominal)
  - Distal emboli (extremities) or pulmonary embolism
- Immediate/periprocedural complication(s)
  - Pulmonary embolism (venous)
  - Reperfusion syndrome (arterial)
    - Inflammatory response to tissue ischemia/death
    - Symptoms range from limb swelling to systemic inflammation with multiorgan failure and death
    - Treatment may include fasciotomy to relieve compartment syndrome, anticoagulation to prevent further thrombosis, or amputation
  - Allergic response to thrombolytic
  - Vessel dissection
- Delayed complication(s)
  - Hematoma formation at access site
  - Recurrence of thrombosis
  - Catheter site infection
    - Prophylactic antibiotics suggested for prolonged (> 72 hours) thrombolysis

Expected Outcomes

- Symptomatic improvement following successful thrombolysis
  - Shorter lesions associated with good clinical outcomes
- Visualization of potential underlying vessel pathology/compression/stricture

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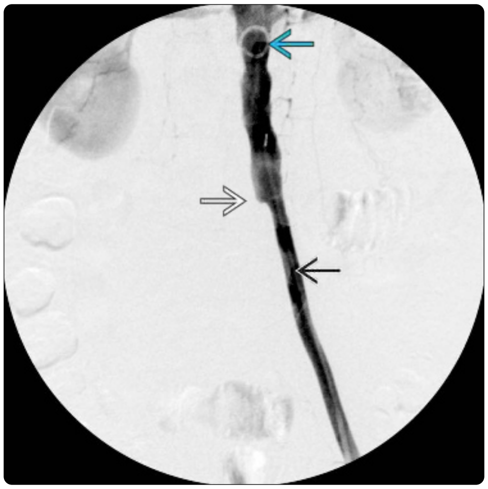
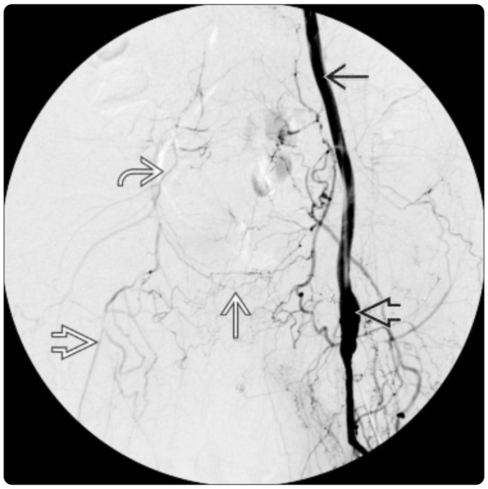
Bypass Graft Thrombolysis (Aortoiliac DSA, Occluded Right Bypass Graft)

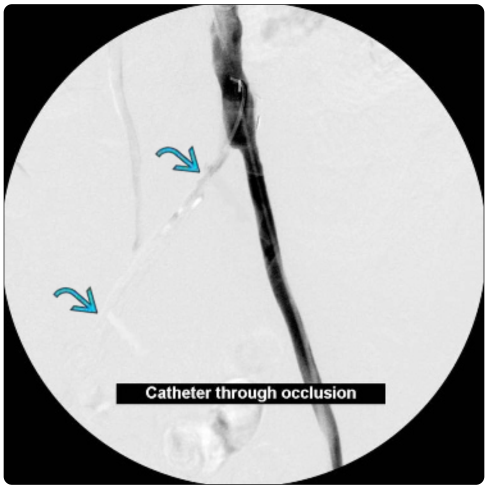


Bypass Graft Thrombolysis (Iliofemoral DSA, Pelvic Collaterals)

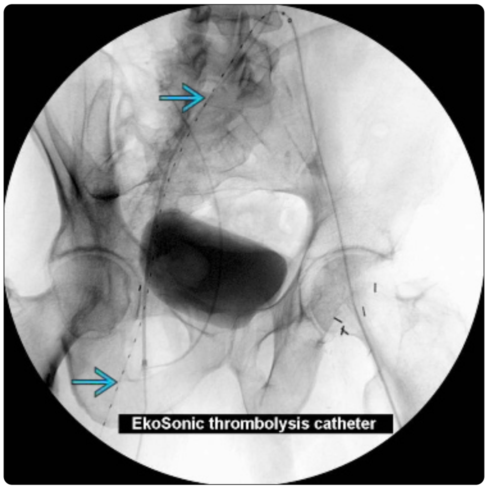


(Left) *DSA in a patient with new right lower extremity ischemia, who previously had aortobifemoral bypass graft surgery for occlusive disease, shows a pigtail catheter* → *has been placed in the distal aorta via the patent left graft limb* →. *The right iliac limb* ➔ *is occluded at the graft bifurcation.* **(Right)** *Pelvic DSA shows the patent right graft* → *distal anastomosis* ⇨. *Small transpelvic* ➔ *and right internal iliac* ↪ *artery collaterals reconstitute diminutive runoff vessels* ➩ *in the right lower extremity.*

Bypass Graft Thrombolysis (Initial Traversal of Thrombosis)

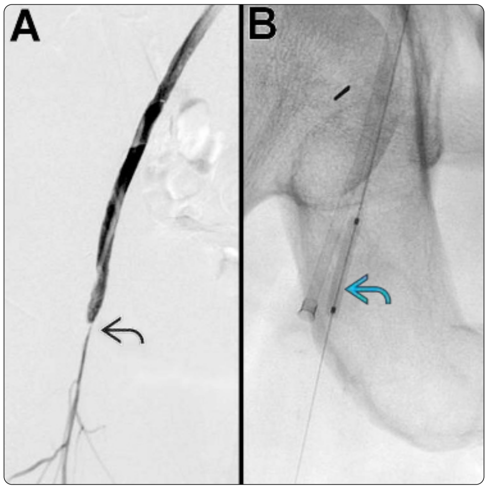


Bypass Graft Thrombolysis (Thrombolysis Catheter Placement)

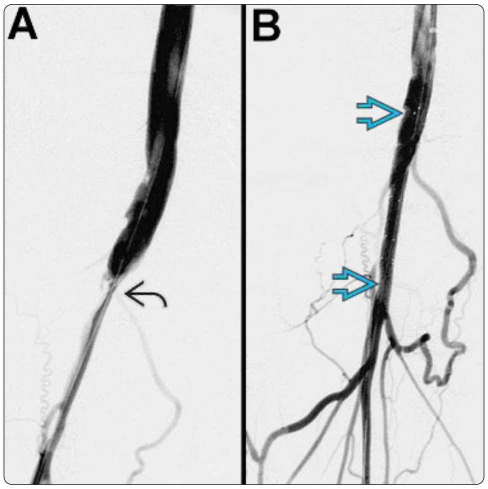


(Left) *Antegrade guidewire passage through the occlusion, using a reverse-curve catheter at the graft bifurcation, was unsuccessful. The distal anastomosis of the thrombosed right limb was accessed, and a guidewire and catheter* ↪ *were passed retrograde through the occlusion.* **(Right)** *A left-sided guidewire was snared by a right-sided catheter and withdrawn into the occluded limb. Over this wire, an EkoSonic thrombolysis catheter* → *was advanced. The tip was positioned in the right profunda femoral artery.*

Bypass Graft Thrombolysis (Underlying Stenosis Unmasked)



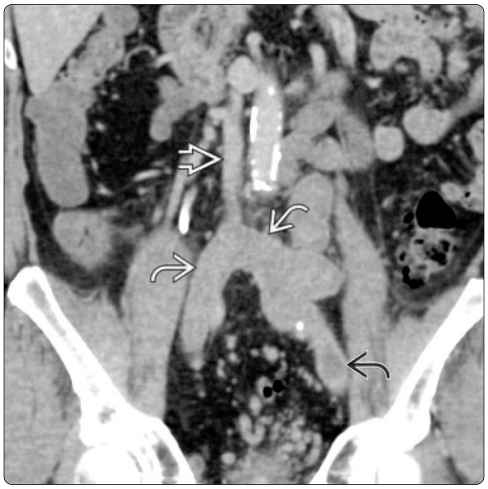
Bypass Graft Thrombolysis (Treatment of Underlying Stenosis)



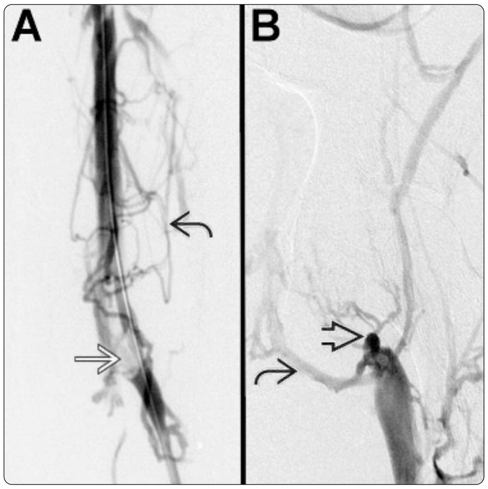
(Left) *Twelve hours after continuous tPA infusion (0.5 mg/h), repeat DSA was performed to assess the thrombolysis efficacy. (A) Severe stenosis* ↪ *of the graft distal anastomosis was discovered (likely the cause of thrombosis). (B) Angioplasty* ↪ *of the stenosis was performed.* **(Right)** *(A) There was only slight improvement in the stenosis* ↪ *after angioplasty. (B) Flexible covered intravascular stents* ⇨ *were placed across the refractory stenosis. Surgical anastomotic revision would be alternative treatment option.*

(Left) *Coronal NECT in a patient with severe bilateral lower extremity swelling shows marked dilatation of the common iliac veins ↪ below a severely narrowed IVC ⇨. Thrombus ↪ is seen in the left external iliac vein.* **(Right)** *The patient was placed prone, the left popliteal vein was accessed, and a sheath was placed. (A) DSA venogram shows thrombus ➡ in the femoral vein in the thigh, with extensive collaterals ↪ from chronic DVT. (B) Flow in the femoral vein terminates ⇨ at the femoral head.*

Venous Iliocaval Thrombolysis (Initial CECT)

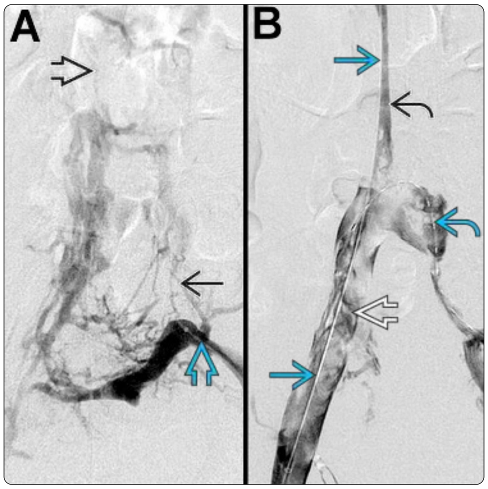


Venous Iliocaval Thrombolysis (Initial DSA)

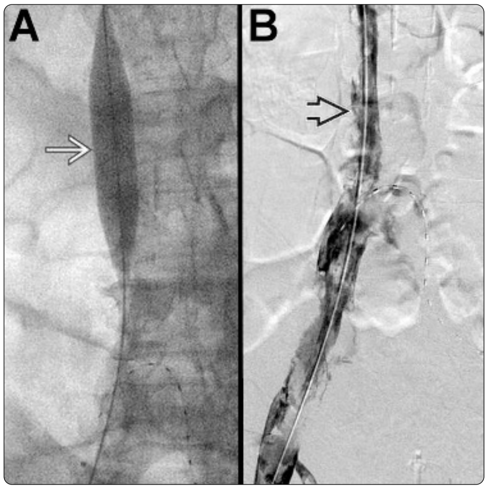


(Left) *(A) DSA via a left-sided catheter → shows left iliac vein → occlusion and no IVC ⇨ contrast. (B) A right groin guidewire → was advanced through the thrombosed iliac vein ⇨ into the atretic IVC ↪. After traversing the left iliac occlusion, an EkoSonic catheter ↪ was placed from the left into the right iliac vein.* **(Right)** *(A) After angioplasty ⇨ of the IVC, (B) DSA showed improved IVC caliber ⇨. Bilateral thrombolysis catheters were advanced to the IVC. IVC filter placement could be considered.*

Venous Iliocaval Thrombolysis (US-Accelerated Thrombolysis)

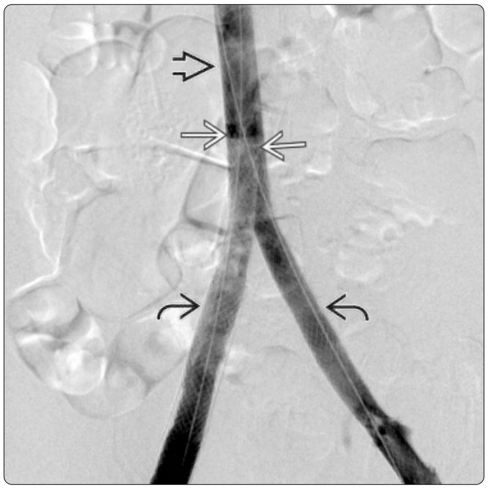


Venous Iliocaval Thrombolysis (IVC Angioplasty)

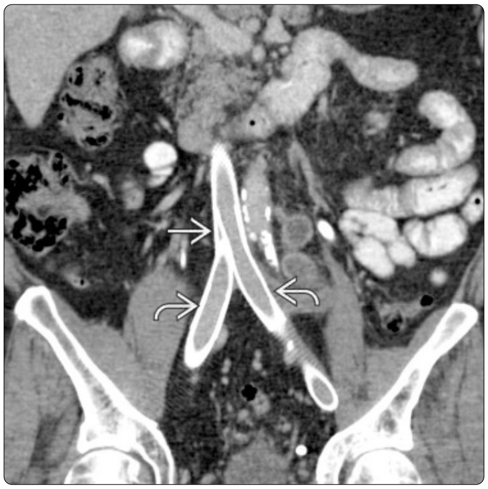


(Left) *There was marked decreased thrombus burden in the iliac veins following tPA CDT. Due to underlying stenosis, a large-caliber Wallstent ⇨ was placed in the IVC, and bilateral smaller caliber Wallstents ↪ were placed in both iliac veins and extended so that the proximal ends ➡ terminated inside the IVC stent.* **(Right)** *Coronal CECT 2 months after treatment shows patent bilateral iliac Wallstents ↪ extending cephalad into the IVC stent, a small portion ➡ of which can be seen.*

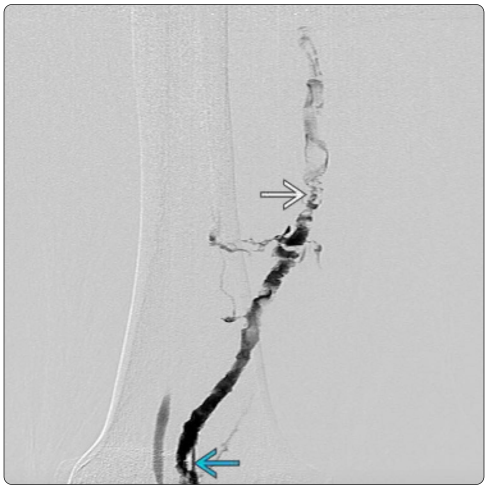
Venous Iliocaval Thrombolysis (Stenting Underlying Venous Stenosis)



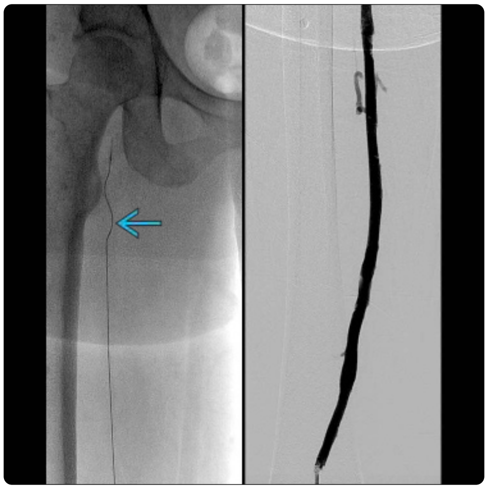
Venous Iliocaval Thrombolysis (Follow-Up CECT)



Mechanical Thrombectomy of Femoral Vein (DSA, Isolated Femoral Thrombus)

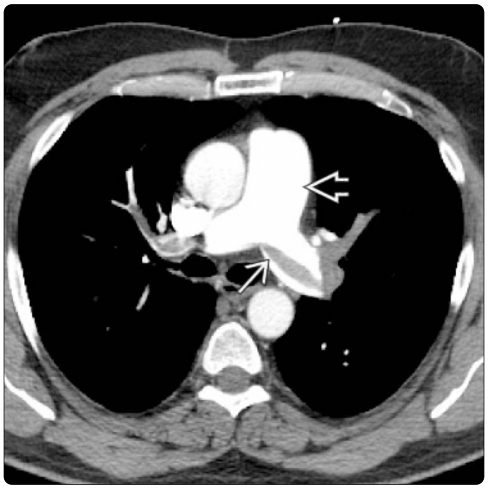


Mechanical Thrombectomy of Femoral Vein (Post Treatment)

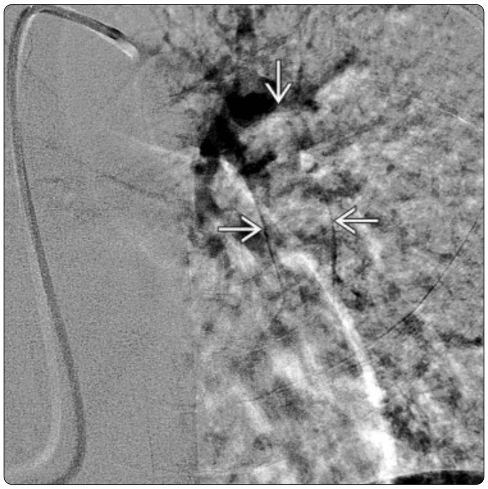


(Left) *Due to patient's strong desire to treat aggressively, endovascular therapy was requested in an active 42-year-old man with isolated femoral vein thrombus. DSA obtained via a popliteal sheath ⇨ shows subacute thrombus ➡, with no significant collateral venous formation.* **(Right)** *8 mg tPA was dispersed into the thrombus through a 5-Fr catheter (plus 4,000 units heparin IV). (A) Mechanical thrombectomy was performed with an Argon Cleaner ⇨. (B) Subsequently, the femoral vein was patent and without underlying stenosis.*

Pulmonary Embolism (Diagnostic CT)

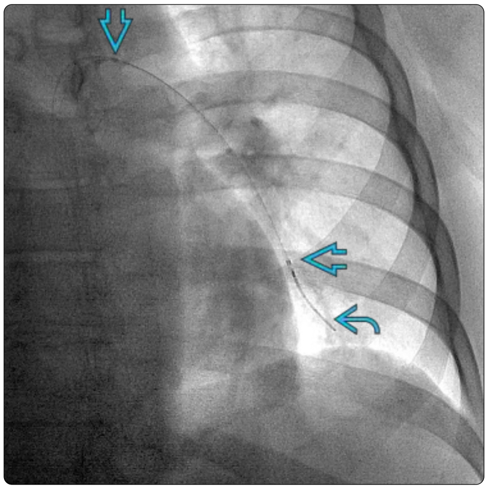


Pulmonary Embolism (Left Pulmonary Angiogram)

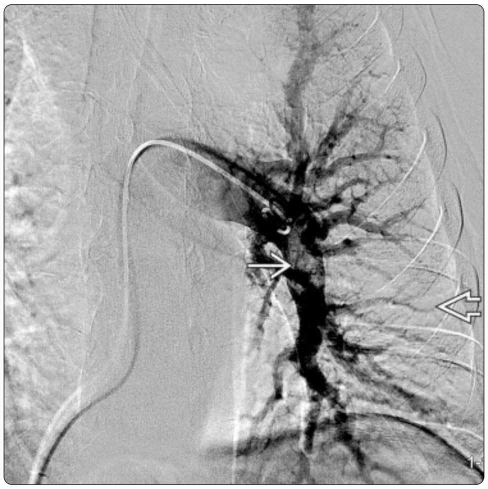


(Left) *Axial CECT in a patient with dyspnea reveals saddle pulmonary embolism ➡ and enlargement of the main pulmonary artery ➡.* **(Right)** *Digitally-subtracted left pulmonary angiogram confirms occlusive thrombus ➡, most severe in the left lower lobe (LLL). Main pulmonary artery pressures were elevated as well.*

Pulmonary Embolism (Placement of CDT Infusion Catheter)

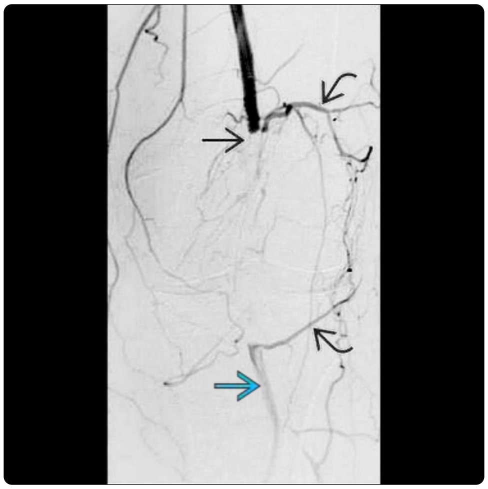


Pulmonary Embolism (Postthrombolysis)

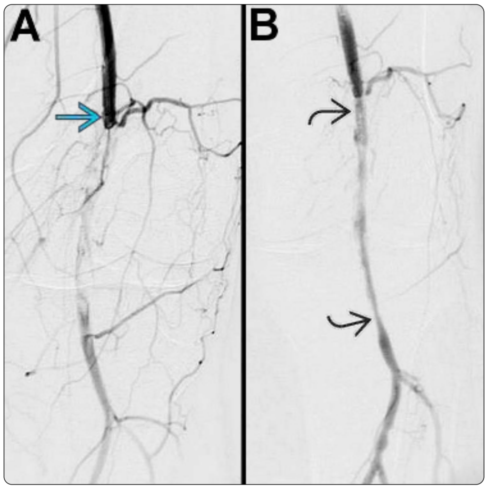


(Left) *An infusion catheter was advanced into the LLL pulmonary artery. Radiodense markers ⇨ border the length of infusion side-ports. An internal occlusion wire ⇨ blocks the end of the catheter, forcing thrombolytics to flow out through the side-holes.* **(Right)** *Following 20 hours of CDT (tPA 1 mg/hr), DSA shows LLL flow markedly improved. However, partially occlusive thrombus remains ➡, and many distal branches are truncated ➡. At this point, a determination must be made to halt CDT, continue CDT, or initiate CDT in the right lung.*

(Left) *A patient presented with acute left leg ischemia. DSA shows an abrupt above-knee popliteal artery occlusion →, with reconstitution of the below-knee arterial segment → via small collaterals ↷.* **(Right)** *(A) Because a guidewire would not advance across the occlusion, thrombolysis was started via an end-hole catheter → placed above the occlusion. (B) After 12 hours, some patency ↷ was restored, but with marked luminal irregularity. This was accepted as the final result, and the patient discharged on Coumadin.*

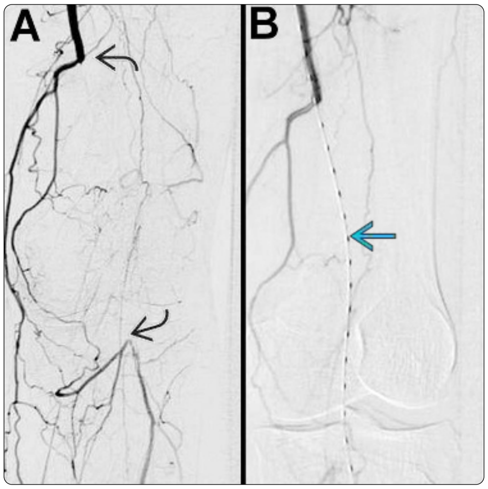


Suboptimal Intraarterial Thrombolysis (Initial DSA)

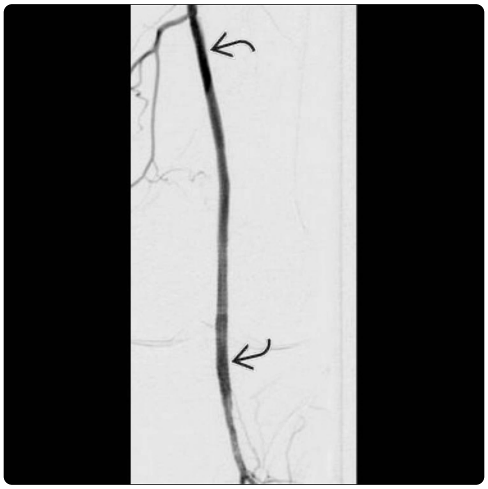


Suboptimal Intraarterial Thrombolysis (Postthrombolysis DSA)

(Left) *(A) The patient returned 1 week later with recurrent left leg ischemic symptoms. Reocclusion of the popliteal artery ↷ extends more cephalad than previously. (B) The occluded segment was crossed with an EkoSonic catheter →, and tPA-CDT was initiated.* **(Right)** *Following intraarterial thrombolysis, patency was restored to the popliteal artery. However, because there was a very irregular appearance to the artery on the postthrombolysis DSA, a covered intravascular stent ↷ was placed.*

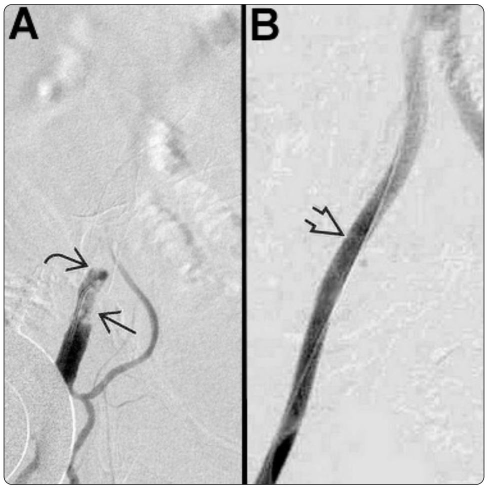


Suboptimal Intraarterial Thrombolysis (Recurrent Arterial Thrombosis)

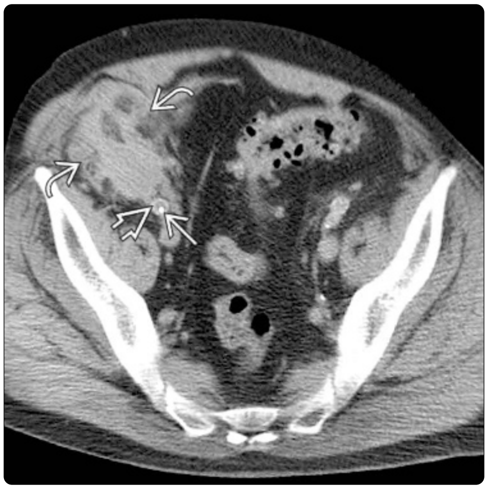


Suboptimal Intraarterial Thrombolysis (Postthrombolytic Stent Placement)

(Left) *(A) Initial DSA in a patient with acute occlusion of the right limb of an aortobifemoral bypass shows thrombus → distally and nonfilling of the limb ↷ proximally. (B) Intraarterial thrombolysis restored graft patency ⇨.* **(Right)** *Pelvic CT was obtained after the patient became hypotensive and complained of right groin pain. A hematoma ↷ in the right hemipelvis, adjacent to the graft ⇨ and internal thrombolysis catheter ➡, halted further thrombolysis. Fortunately, limb patency had been restored.*

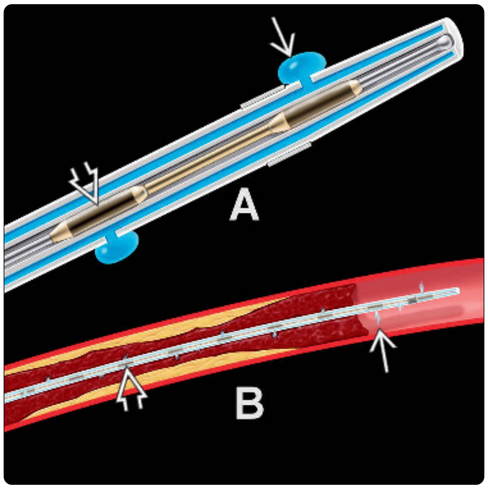


Complication of Thrombolysis (Spontaneous Hematoma)

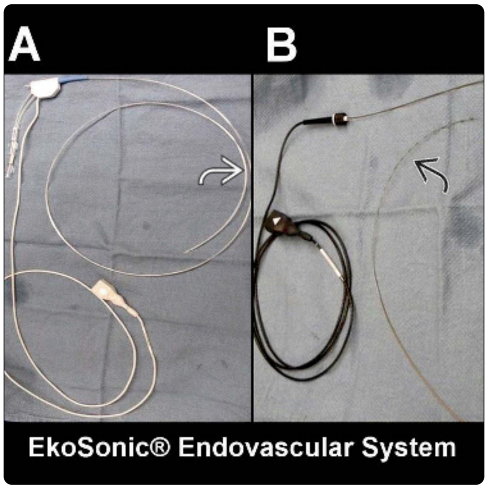


Complication of Thrombolysis (Spontaneous Hematoma)

US-Accelerated Infusion Catheter (Graphic Representation)

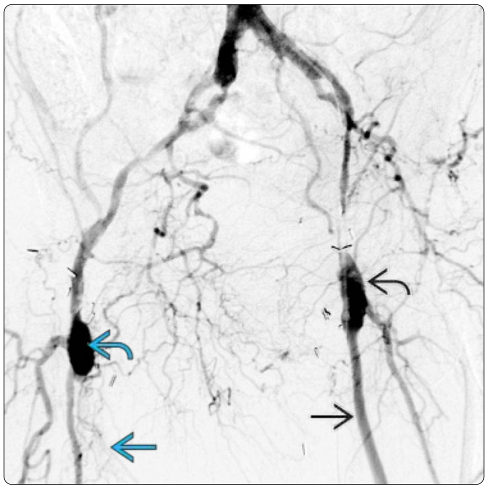


US-Accelerated Infusion Catheter (EkoSonic Infusion Catheter)

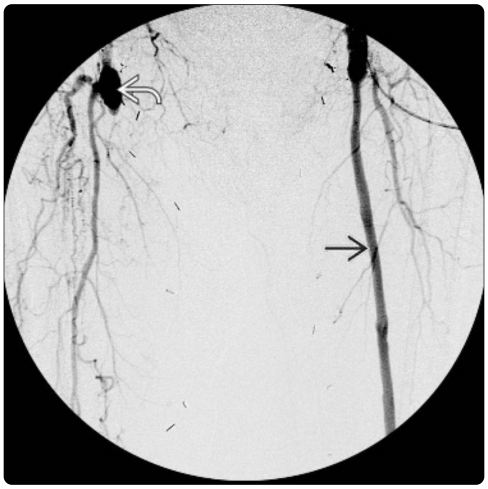


(Left) *US-assisted infusion catheters have (A) an infusion catheter with multiple sideholes from which thrombolytics are delivered →, and an inner core wire with multiple US microtransducers ⇨ transmitting high-frequency energy. (B) The catheter assembly is positioned to disperse thrombolytics across the entire occlusion.* **(Right)** *Shown is the EkoSonic (A) infusion catheter ↪ and (B) inner core wire with multiple US microtransducers ↪.*

Arterial Femoropopliteal Bypass (Pelvic DSA, Occluded Right Graft)

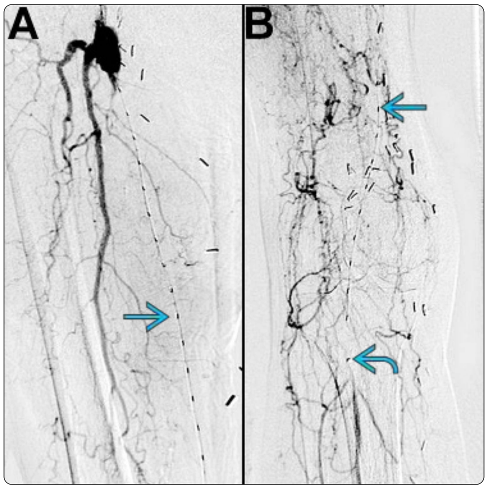


Arterial Femoropopliteal Bypass (Femoral DSA, Occluded Right Graft)

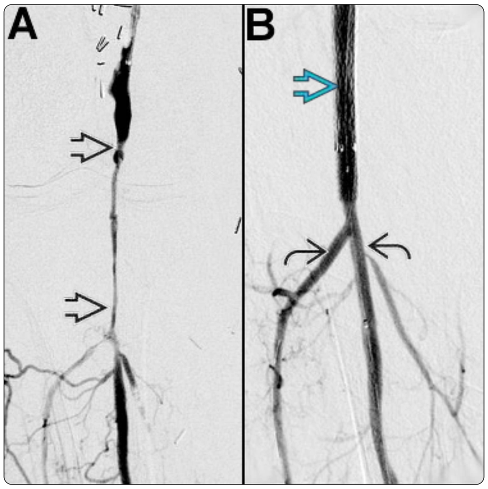


(Left) *A patient with prior bilateral femoropopliteal bypass surgery presented with new onset of severe right leg ischemia. DSA shows a patent left bypass graft → arising from a normal proximal anastomotic graft hood ↪. The right graft hood ↪ is also seen, but the graft → is not identified below this level.* **(Right)** *DSA at proximal thigh level again confirms a patent left femoropopliteal bypass graft →. The previously identified right bypass proximal anastomotic graft hood ↪ terminates blindly.*

Arterial Femoropopliteal Bypass (Catheter-Directed Thrombolysis)



Arterial Femoropopliteal Bypass (Postthrombolytic DSA, Unmasked Stenoses)



(Left) *(A) A guidewire successfully traversed the occluded graft and an EkoSonic thrombolysis catheter was placed. Radiopaque microtransducers → are seen. (B) The catheter tip ↪ is in the below-knee popliteal artery.* **(Right)** *(A) Following tPA thrombolysis, DSA uncovered severe popliteal artery stenotic disease ⇨ felt to be the cause of the graft thrombosis. (B) A covered stent ⇨ was placed in the diseased popliteal artery, and angioplasty of the proximal runoff vessels ↪ was performed.*

Embolization

KEY FACTS

TERMINOLOGY

- **Embolization**: Therapeutic technique using direct/transcatheter introduction of intravascular agent for hemorrhage control/devascularization/occlusion
    - **Temporary agents**: Vessel recanalization unpredictable, usually occurring within weeks to months
    - **Coils**: Mechanical metal occluding device; coiled configuration upon exiting catheter, blocks vessel
    - **Particles**: Micron-sized solids; lodge at precapillary/capillary level; occlude vessels/devascularize tissue
    - **Plug occluding device**: Woven nitinol expandable mesh cylindrical plug
    - **Liquids**: Flow/distribute through complex vascular structures; may solidify to occlude vessel(s)
    - **Sclerosing agents**: Liquid irritant causing vessel occlusion via inflammation/thrombosis
    - **Oncologic**: Deliver chemotherapy/radioisotope

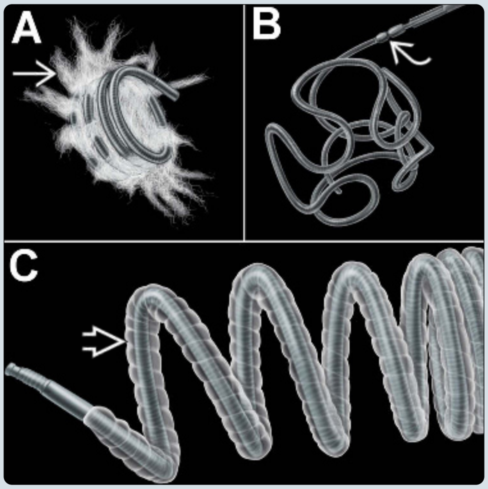
PREPROCEDURE

- **Various indications for embolization**
    - Exclusion of potential/actual source of hemorrhage
    - Treatment of vascular malformations
    - Treatment of venous insufficiency
    - Tumor devascularization
    - Adjunct to planned surgery

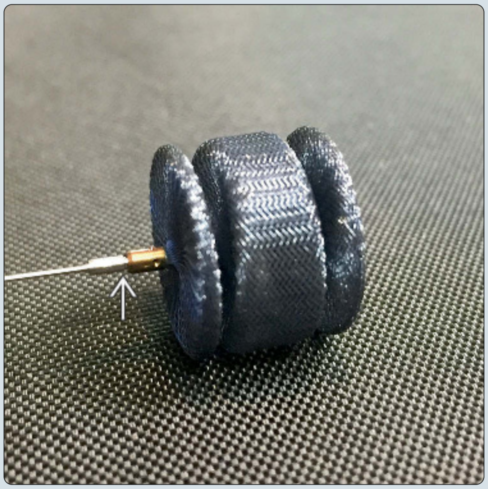
OUTCOMES

- **Potential complications**
    - Nontarget embolization
    - Hemorrhage from intraprocedural vascular rupture, vessel perforation
    - Excessive tissue ischemia resulting in necrosis
- Variable outcomes depending upon embolization target/choice of embolic agent

Coils (Design Options)

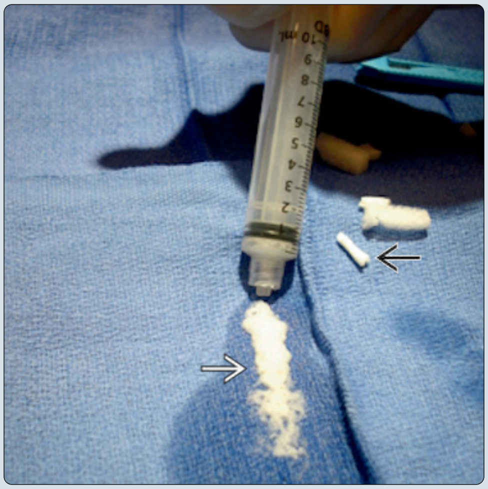


Plug Occluding Device (Amplatzer)

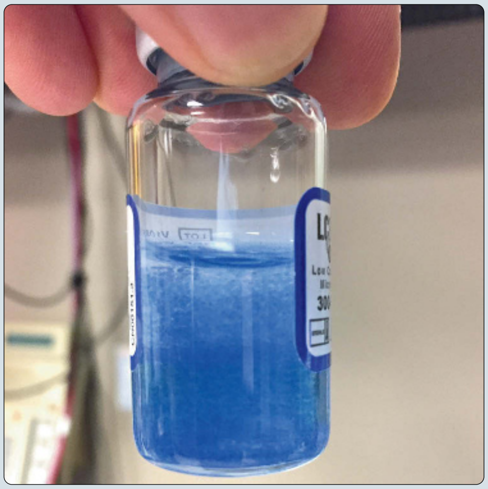


(Left) *(A) A fibered "pushable" coil has thrombogenic fibers* ➡ *extending beyond the radiographically visible metallic frame. (B) A detachable nonfibered framing coil* ➡ *remains attached to the delivery system until precisely placed. Additional smaller coils can be deployed inside the framing coil. (C) Hydrocoils have a layer of hydrogel polymer* ➡ *that expands when the coil contacts blood.* **(Right)** *The Amplatzer self-expands once deployed and is released by counter-clockwise rotation of the hand-held mechanism* ➡*.*

Gelfoam Slurry



Particles (Oncologic Beads)



(Left) *A Gelfoam slurry* ➡ *can be made relatively quickly and deployed intraarterially to gain control of in cases of massive bleed. When the exact focus of bleed cannot be found or accessed, a Gelfoam slurry can rapidly halt blood flow to an entire tissue bed. Note the Gelfoam torpedo* ⇨*.* **(Right)** *Spherical particles flow from a catheter and embolize distally at a precapillary level, devascularizing tissues. The beads shown are tinted blue for easy visualization and are used as a delivery agent for chemotherapeutics delivered to hepatic tumors.*

TERMINOLOGY

Definitions

- **Embolization**: Therapeutic technique using direct/transcatheter introduction of intravascular agent for hemorrhage control/devascularization/occlusion
  - Various available agents
    - Subclassified as temporary and permanent agents
- **Temporary embolic agents**
  - Gelatin sponge
    - Gelfoam (Upjohn; Kalamazoo, MI)
      - Sheet form; can cut into pledgets/create slurry
    - Surgifoam (Ethicon; Somerville, NJ)
      - Sheet form similar to Gelfoam
      - Powder form (40- to 60-μm particle diameter) causes distal occlusion; possible ischemia/infarction
    - Consider use to rapidly embolize arterial hemorrhage, combine/sandwich with coil embolization, temporarily occlude shunting prior to definitive treatment, occlude percutaneous transhepatic access, or when permanent embolization not ideal
      - Not ideal for small vessel embolization
    - Inexpensive, readily available, rapid preparation and effect
    - May be prepared as single torpedo or slurry
    - Recanalization of embolized vessel is unpredictable, usually occurring within weeks to months
  - Autologous clot
    - Delivery of patient's thrombosed blood products
    - Short effective duration (hours)
- **Permanent embolic agents**
  - **Coils**: Mechanical metal occluding device; assumes coiled configuration upon exiting catheter, blocks vessel with fibers, swelling hydrogel; various sizes, configurations and shapes (e.g., straight, tornado-tapered shape, 2D or 3D shapes)
    - Consider coil use when catheter can be advanced to targeted vessel
    - **"Pushable" 0.035" or 0.018" coils**: Inexpensive, straight-forward delivery
      - Azur peripheral pushable HydroCoil (Terumo)
      - Nester, Hilal, Tornado embolization coils (Cook Medical; Bloomington, IN)
      - VortX embolization coils (Boston Scientific)
    - May be advanced and deployed through catheter with "coil-pusher" wire or careful (semiforceful) injection with 1- to 3-cc syringe of saline
    - May not be possible to remove/snare if malpositioned
    - **Detachable 0.035" or 0.018" coils**: May be retrieved if in suboptimal location/configuration
      - Axium detachable coil (ev3; Plymouth, MN)
      - Azur HydroCoil (Terumo; Somerset, NJ)
      - GDC, Interlock, Matrix coils (Boston Scientific; Natick, MA)
      - DeltaPaq, DeltaWind microcoils (Micrus Endovascular; San Jose, CA)
      - Orbit Galaxy (Codman Neurovascular)
    - Consider detachable coil use in critical vessels, high-flow shunts or areas where nontarget embolization could inadvertently occur (e.g., gastroduodenal artery)
    - Retrieval not always possible if coil fully deployed or too much time elapsed
    - Multiple detachment designs exist (e.g., mechanical, electrical)
  - **Particles**: Micron-sized solids; lodge at precapillary/capillary level; occlude vessels/devascularize tissue
    - Contour PVA (Boston Scientific)
      - Polyvinyl alcohol (PVA) particles; nonspherical irregular sizes
      - Occlude more proximal than vs. similar-sized spherical particle (bead)
      - Can clump, resulting in proximal vessel/catheter occlusion
    - PVA foam embolization particles (Cook Medical)
    - Contour SE microspheres (Boston Scientific)
      - Calibrated PVA microspheres (teardrop shape)
    - Bead Block (Terumo Medical)
      - Calibrated PVA hydrospheres
    - Embospheres (Biosphere Medical; Rockland, MA)
      - Calibrated acrylic polymer microspheres
      - Slightly compressible during delivery
      - EmboGold variant tinted red
    - Embozene microspheres (CeloNova BioSciences; Peachtree City, GA)
      - Hydrogel microsphere with Polyzene-F coating
    - Consider use within end-arteries when distal arteriole/organ embolization desired
    - May lead to significant embolization and subsequent ischemia of distal tissue/organ
    - Do not use in cases of vascular shunting or collateral vasculature
    - Concerns include nontarget embolization
  - **Plug occluding device**: Woven nitinol expandable mesh cylindrical plug
    - Amplatzer Vascular Plug (St. Jude Medical; Saint Paul, MN)
      - Mechanically occludes target vessel in similar manner to coil embolization
      - Allows precise positioning, short landing zone, rapid occlusion
      - Recommended to oversize 30% beyond target vessel diameter
      - AVP 4 design delivered via 0.038" catheter
      - Less trackable through tortuous vessels vs. coils
  - **Liquids**: A variety of nonsolid embolic
    - Consider use for specific clinical situations: Complex embolic target requiring embolic penetration beyond catheter into nidus [arteriovenous malformation (AVM)], desire to solidify target vessel (intracranial aneurysm), oncologic use (hepatocellular carcinoma), nonvascular target (biliary leak)
    - Sufficient training and well-developed understanding of each specific liquid embolic's properties and risks is necessary prior to use
    - Delivery of liquid embolics often require advanced training and experience and can be challenging to properly deploy
    - Ethanol: 96-98%, immediately denatures cellular proteins/causes small vessel thrombosis
      - Can be used to ablate whole organ (e.g., kidney)

    - Also useful as sclerosant
    - Extremely painful during delivery; consider general anesthesia
    - **Caution**: Ensure ethanol not injected where shunting is present
    - Not visible during delivery (unless mixed 4:1 with Lipiodol); calculate desired volume of ethanol using dilute contrast
  - Lipiodol (Guerbet; Paris, France): Ethiodized oil; iodine-containing poppy seed oil
    - Used in conventional transarterial chemoembolization where it acts as fluoroscopically visible chemotherapeutic delivery agent and transient arterial embolic
    - Can occlude lymphatic leaks (50-75%) during lymphangiogram
    - Added to other embolics during delivery (e.g., ethanol, "glue")
    - Dissolves soft plastics (e.g., catheter hub, syringe, 3-way stopcock)
  - N-butyl cyanoacrylate (n-BCA) Trufill (Cordis; Bridgewater, NJ)
    - Solidifies on contact with ionic medium (e.g., blood)
    - Liquid "glue" polymer is mixed with Lipiodol immediately prior to delivery
    - Ratio with more Lipiodol (5:1) slows rate of glue polymerization/solidification; ratio with less Lipiodol (2:1) increases rate of polymerization/solidification
    - Nonionic preparation of table, gloves, catheters, syringes vital
    - All equipment must be meticulously flushed with nonionic solutions (e.g., D5W)
    - "Glue" is flushed through catheter with nonionic solution
    - Typically, small volumes of n-BCA/Lipiodol necessary
    - Caution: Catheter can become "glued" to vessel during delivery
    - Has nonvascular applications, since occlusion does not require platelets/coagulants
  - Onyx (ev3 Neurovascular; Irvine, CA)
    - Ethylene vinyl alcohol copolymer dissolved in dimethyl sulfoxide (DMSO)
    - Radiopaque-suspended micronized tantalum powder added for increased visibility; tantalum may become visible through skin if treating superficial vascular malformations
    - Precipitates from outside-in on contact with aqueous solution as DMSO dissipates
    - Forms "foam" embolic with lava-like flow characteristics
    - Nonadhesive; catheter very unlikely to stick to vessel during delivery; allows slower, more deliberate injection vs. n-BCA "glue"
  - Thrombin solution
    - Off-label use, percutaneously thrombose access-related pseudoaneurysms
    - Rapidly converts fibrin to fibrinogen, activates coagulation cascade; causes thrombotic occlusion of target
    - Be aware that label warns not for intravascular injection
    - Extremely small volumes (0.2-0.5 cc) typically necessary
    - Severe potential effects of nontarget embolization; Doppler distal pulse during delivery
    - **Caution**: Do not use if patient had prior allergic reaction to thrombin
- **Sclerosing agents**
  - Detergents: Causing vessel occlusion via inflammation/thrombosis
    - Consider use in varicose veins, venous malformations, pelvic congestion syndrome, balloon-occluded retrograde transvenous obliteration
    - Can use as liquid, or mix with air (or CO2) to form foam
    - Advantage of foam: Increased contact with wall, with less-administered sclerosing agent
    - **Sodium tetradecyl sulfate**-STS (Sotradecol): Mild sclerosant; typically 3% STS (available in 2-mL vials) is mixed with air/CO2 (3 mL air: 2 mL STS: Add 1 mL Lipiodol for visualization as needed)
    - Polidocanol: Widely used in Europe
    - Ethanolamine oleate iopamidol (Ethamolin): Widely used in Japan
    - Sodium morrhuate (Scleromate): Fallen out of favor
  - Ethanol: Immediate protein denaturation and cell death
  - Boiling contrast: Not often used due to patient pain, operator risk
  - Lymphocele sclerotherapy
    - Doxycycline: Intracavitary injection effective for treatment of lymphatic malformations, inexpensive, widely available
    - Intracavitary injection of tetracycline, bleomycin, talc, fibrin glue have also been described
- **Oncologic agents**
  - Consider use in specific oncologic situations
  - Drug-eluting beads
    - LC Beads (DC Beads in Europe) (AngioDynamics, Latham, NY): Blue tint, sizes include 100-300 μm, 300-500 μm, and 500-700 μm
    - QuadraSphere (Merit Medical, South Jordan, UT) spheres enlarge over time: 30-60 μm, 50-100 μm, 100-150 μm, and 150-200 μm
    - Chemotherapeutics are bound to spheres ionically (irinotecan) or osmotically (doxorubicin) and delivered to tumor where chemotherapeutics release from beads, resulting in significantly higher concentrations at tumor bed than can be achieved via IV delivery
  - Radioactive particles: Beta-emitting particle, yttrium-90; embedded on microspheres
    - SIR-Spheres (Sirtex Medical; North Sydney, AU); resin microspheres, greater number of particles per dose
    - TheraSpheres (Nordion; Ottawa, Canada); glass microspheres with greater activity per particle
    - Utilized for selective internal radiation therapy
- **Stents**: Used in association with embolization coils

    - Stent-assisted coil embolization: Noncovered stent placed across wide neck aneurysm
      - Coils introduced through stent interstices into aneurysm/pseudoaneurysm using microcatheter

PREPROCEDURE

Indications

- Exclusion of potential/actual source of hemorrhage
  - Aneurysm
  - Arteriovenous fistula
  - Bronchial artery inflammation
  - Pseudoaneurysm
  - Varices associated with portal hypertension
    - Esophagogastric, mesenteric, peristomal
  - Vascular perforation/rupture
- Treatment of vascular malformations
  - Congenital/acquired AVM/venous malformation
- Treatment of venous insufficiency
  - Associated with venous valvular incompetency
    - Pelvic congestion, male varicocele
    - Saphenous vein incompetency
- Tumor devascularization
  - Solid benign/malignant neoplasms
    - Must be vascular for embolization to be effective
- Adjunct to planned surgery: e.g., portal vein embolization prior to partial hepatectomy, preresection tumor devascularization

Contraindications

- Contrast allergy
- Renal insufficiency
- Uncorrectable coagulopathy/bleeding diathesis

PROCEDURE

Procedure Steps

- **General transarterial/transvenous technique**
  - Sterilely prepare/drape intended access site
  - Obtain arterial/venous access
  - Place vascular access sheath (as needed)
  - Introduce 4- to 5-Fr catheter/guidecatheter via sheath
  - Selectively place guidecatheter in target vessel
    - Inject contrast; obtain DSA images
  - Coaxially introduce microcatheter via guidecatheter
    - Negotiate microcatheter into target lesion
  - Obtain DSA images through microcatheter
    - Confirm target appropriate for embolization
      - Confirm planned embolic agent appropriate
    - Confirm catheter position for embolization
      - Confirm flow rate for embolization if using liquids/particles
    - If treating AVM, embolization of AVM nidus crucial for success
      - Must occlude nidus to eliminate AVM
      - Proximal arterial feeder embolization ineffective
  - Proceed with embolization
    - Monitor fluoroscopically during embolization
  - After embolization, obtain completion DSA images
    - Document results of embolization
      - Confirm satisfactory occlusion/treatment
    - Confirm preservation of vital vascular pathways
  - Remove sheaths/catheters
    - Obtain hemostasis at arterial/venous access sites
      - Manual compression vs. closure device
- **Gelfoam embolization technique**
  - Provided as gelatin sponge sheet
    - Sheet can be cut into pledgets
      - Can compress pledgets into syringe; deliver through catheter via forceful liquid injection
    - Can form Gelfoam slurry
      - Cut pledgets, place in 5- to 10-mL syringe; attach to 3-way stopcock
      - Attach 2nd fluid-filled contrast syringe to stopcock
      - Agitate fluid/Gelfoam across stopcock between syringes; forms slurry
  - Typically used as temporary embolic agent
    - Vessel recanalization can occur over 2-5 weeks
      - Composed of water-insoluble gelatin
      - Absorbs liquid/occludes vessel
    - Permanent embolization/occlusion unnecessary
      - Expected healing/resolution of vascular insult
  - Selective catheter placed proximal to target
    - Sometimes used for nonselective embolization in absence of active extravasation
      - e.g., empiric internal iliac artery embolization in hypotensive patient after pelvic trauma
    - Inject pledgets/slurry under fluoroscopy
- **Coil embolization technique (general)**
  - Place sheath, introduce diagnostic catheter
    - Position selective catheter in target vessel
  - Obtain diagnostic DSA
    - Analyze images, plan embolization
  - May use either 0.035" or 0.014-0.018" system
    - Introduce coaxial microwire/catheter for microcoils
      - Position microcatheter tip for embolization
  - Proceed with coil embolization
    - May use roadmap fluoroscopy during coiling
    - Monitor fluoroscopically during coiling
  - Use coils slightly larger than target diameter
    - If treating aneurysm, frame with 3D-type coil first
      - After 1 or more 3D framing coils deployed, place filling coils followed by finishing coils
    - May use detachable coils for precise placement
      - Can retrieve/reposition coil until detached from deployment system
      - May follow with pushable coils
      - Avoid protrusion of coils into any adjacent vessels where patency is to be preserved
    - Use intermittent contrast injection during coiling
      - Verify coil positions/assess embolization progress/adequacy
  - When coiling complete, obtain DSA before removing catheter/microcatheter
    - Document final result, any abnormalities
  - **Stent-assisted coiling technique**
    - Useful for wide-necked aneurysms
      - Allows coiling of aneurysm sac without coil protrusion into adjacent/parent vessel
    - Place microwire/microcatheter beyond aneurysm
    - Measure target vessel size, stent length

      - Advance/deploy stent across aneurysm neck
      - Place microcatheter through stent interstices into aneurysm; inject contrast/confirm position
      - Introduce coils into aneurysm via microcatheter
  - **Balloon-assisted coiling technique**
    - Also useful for wide-necked aneurysms
      - Gives temporary balloon support while coiling
      - Mainly used in neurointerventional cases
    - Use 6-Fr guiding catheter
      - Use systemic heparinization
    - Via guiding catheter, coaxially introduce balloon; place across aneurysm neck
    - Via guiding catheter, place coaxial microcatheter into aneurysm, inflate balloon across neck
    - Place framing coils with balloon inflated
      - Deflate balloon before detaching coil to see conformation, relationship with parent vessel
      - Balloon only transiently inflated (~ 2 min)
    - After framing coils, place filling/finishing coils
      - Can safely insert latter without inflating balloon
    - Inflate balloon when removing microcatheter
      - Prevents coil dislodgement
- **Particle embolic agent technique**
  - Selectively catheterize target artery
    - Obtain/analyze DSA images
  - Coaxially place microcatheter via selective catheter
    - Use microcatheter for superselective catheterization of target artery/lesion
      - May use roadmap fluoroscopic guidance
    - Obtain repeat DSA with catheter tip positioned in vessel before therapeutic injection
      - Confirm anatomy/satisfactory catheter position
      - Proximal occlusion with particles generally undesirable; inadequate devascularization
    - Determine appropriate particle size for embolization based on DSA/other imaging
      - If using spherical embolics, 100- to 300-μm particles provide deep penetration/more devascularization
      - 300-500 μm penetrates less deeply
      - If significant arteriovenous shunting present, may need larger particles (e.g., ≥ 500-700 μm)
  - Perform embolization
    - Mix embolic agent with dilute contrast
    - Administer embolic agent very slowly
      - Administer into target vessel under fluoroscopy; confirm antegrade flow toward target
      - Inject in nonforceful, pulsatile manner to avoid/minimize potential for reflux
  - Embolization endpoint
    - Embolize to stasis/near-stasis
      - Contrast stasis in artery for 5-10 heart beats
      - Reflux of contrast toward parent artery origin
- **Plug occluding device technique**
  - Selectively catheterize target artery
    - Inject contrast; obtain DSA images
      - Analyze images, plan embolization
  - Determine appropriate size/configuration plug occluding device for embolization; based on vessel type, blood flow, available "landing zone"
    - Amplatzer Vascular Plug: Short "landing zone"/single-layer mesh/single-lobe design
      - Placed via sheath
    - Amplatzer Vascular Plug II: Variable "landing zone"/multilayered mesh lobes/large surface area
      - Diameters range from 3-22 mm
      - Placed via sheath
    - Amplatzer Vascular Plug III: For high-flow target embolization/multiple mesh layers/extended rims
      - Results in very rapid occlusion
      - Placed via sheath (currently unavailable in USA)
    - Amplatzer Vascular Plug IV: Low-profile plug
      - Delivered via 0.038" diagnostic catheter
      - Bilobed configuration; 11-mm length plug with diameters ranging from 4-8 mm
  - Should use plug occluder sized 30-50% larger than vessel diameter at intended occlusion site
  - Must be able to advance delivery sheath into target vessel for plug placement (only low-profile device can be delivered via catheter)
    - Device is self-expanding
      - Retract sheath for delivery
      - Can recapture, reposition device until detached
  - After deployment, inject contrast, obtain DSA
    - Confirm satisfactory occlusion
- **Liquid embolic agent technique**
  - **General**
    - Liquids provide excellent penetration/occlusion
    - Delivery/dispersal sometimes difficult to control
      - Potential for nontarget embolization, especially if high-flow hemodynamics
      - Inject selectively into vessels supplying target; may otherwise injure adjacent normal tissue
  - **Ethanol technique**
    - Ethanol use painful; depending upon target size/location may need anesthesia support
    - Use direct percutaneous or transcatheter access
      - Depends on target type/location
      - Consider direct percutaneous access for superficial and slow-flow vascular malformations
      - Transcatheter access may be used for solid organ embolization, certain high-flow malformations
    - Access target, inject contrast, obtain images
      - Note volume of contrast used to opacify target
      - Look for shunting, avoid or occlude shunting prior to ethanol delivery
    - Determine appropriate ethanol volume for injection based on contrast volume used
      - Initial volume < contrast volume required
      - Limit total ethanol volume per session to < 0.5 mL/kg of body weight (up to 40 mL)
    - Use contrast injections before/after injection
      - Ensure proper distribution/avoid reflux
    - Limit ethanol egress from lesion
      - May use intravascular occlusion balloon for transcatheter technique
      - Tourniquets/manual compression for direct percutaneous technique
      - May occlude venous outflow from target with coils prior to ethanol use

- **n-BCA embolization technique**
  - Draw desired volume of Ethiodol into syringe
    - Mix n-BCA with Ethiodol; higher n-BCA concentration (e.g., 1:2) solidifies faster
    - Proportion mixture concentration according to flow/operator experience
  - Tantalum powder increases radiopacity of n-BCA when mixture > 70% n-BCA
  - Flush microcatheter with D_5W-filled 3-mL syringe
  - Fluoroscopically monitor n-BCA injection
    - Use blank roadmap mask while injecting; allows better visualization of embolic agent
  - Inject dose within several seconds and avoid reflux
  - Quickly withdraw microcatheter
    - Avoids catheter tip being glued into place
- **Onyx embolization technique**
  - Onyx 34 for high-flow fistulas/malformations
  - Onyx 18 for small feeders/slower shunts
  - Flush microcatheter with D_5W-filled 3-mL syringe
    - Flush 3x with D_5W solution
  - Use compatible syringe to draw 1 mL of DMSO
    - Attach DMSO syringe to microcatheter hub
    - Fill dead-space of microcatheter (usually 0.2-0.3 mL) with DMSO over 1-2 min
  - Connect catheter hub and Onyx syringe
    - Keep syringe vertical with plunger down
  - Slowly inject Onyx (~ 0.15 mL/min)
    - Continually monitor injection fluoroscopically
    - Use blank roadmap mask during injection
  - If not going to desired location, pause injection for 15-30 s, then resume injecting
    - Avoid reflux/Onyx entry into normal arteries
    - Avoid occluding normal venous drainage
  - Do not pause injection for > 2 min
    - Onyx may solidify and clog microcatheter
  - To remove microcatheter
    - Aspirate syringe; slowly pull back microcatheter
- **Thrombin embolization technique**
  - Predominantly used for treating access site complications (i.e., iatrogenic pseudoaneurysms)

- **Sclerosant technique**
  - Similar technique to ethanol use
  - Opacify with contrast for fluoroscopic guidance
  - May be diluted with normal saline or air (foam sclerotherapy) for use in cutaneous lesions
    - Limit volume of 3% Sotratetradecol per session to < 0.5 mL/kg of body weight (up to 20 mL)
  - Minimize sclerosant egress from lesion
    - May use intravascular occlusion balloon for transcatheter technique
    - Tourniquets/manual compression for direct percutaneous technique
    - May occlude venous outflow from target with coils prior to sclerosant use
- **Oncologic embolic agent technique**
  - Technique similar to that of bland particle use
  - Very specific indications/techniques for delivery

POST PROCEDURE

Things to Do

- **Clinical management**
  - Control of postembolization syndrome, if present
    - Provide symptomatic pain control
    - Administer antiemetics as necessary
    - Administer antipyretics as necessary
  - Ensure adequate oral intake has resumed
    - Particularly important after extensive ethanol/sclerotherapy treatment
    - Monitor urine output
  - Monitor for any evidence of compartment syndrome after extremity sclerotherapy
    - Evaluate perfusion/neurosensory status

Things to Avoid

- Nontarget embolic occlusion of vessels
- Excessive embolization causing unwanted necrosis

OUTCOMES

Problems

- Can achieve more effective occlusion with ethanol vs. detergent sclerosants
  - Recanalization occurs with both agents
  - Potential for more devastating complications with ethanol vs. detergents

Complications

- Most feared complication(s)
  - Nontarget embolization
  - Hemorrhage from intraprocedural vascular rupture, vessel perforation
  - Excessive tissue ischemia resulting in necrosis
- Immediate/periprocedural complication(s)
  - Contrast-induced nephropathy
  - Postembolization syndrome
    - Pain, low-grade fever, malaise, nausea/vomiting/appetite loss
      - Very common with embolization of neoplasms
  - Skin blistering/pigmentation/ulceration
    - May follow treatment of subcutaneous lesions

Expected Outcome

- Variable outcomes depending upon embolization target/choice of embolic agent

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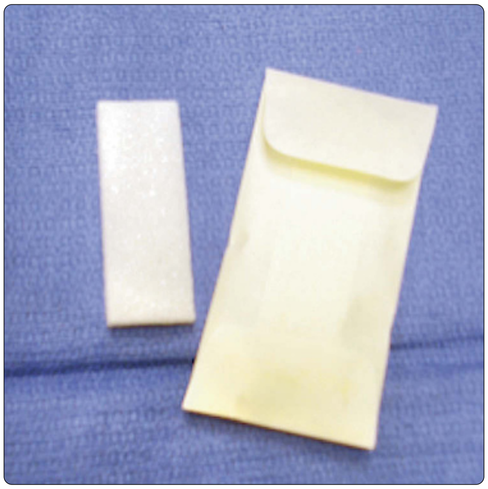
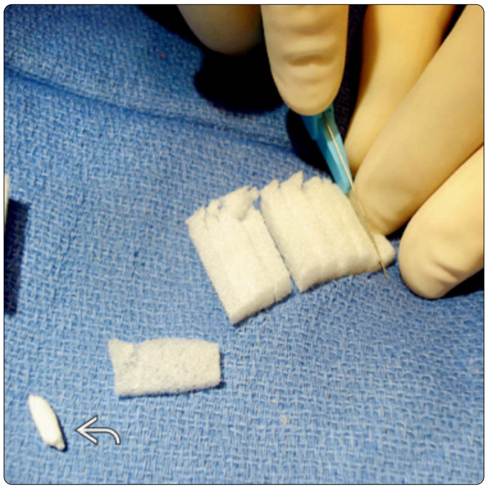
2. Spiotta AM et al: Comparison of techniques for stent assisted coil embolization of aneurysms. J Neurointerv Surg. 4(5):339-44, 2012
3. Etezadi V et al: Endovascular treatment of visceral and renal artery aneurysms. J Vasc Interv Radiol. 22(9):1246-53, 2011
4. Zhu X et al: Utility of the Amplatzer Vascular Plug in splenic artery embolization: a comparison study with conventional coil technique. Cardiovasc Intervent Radiol. 34(3):522-31, 2011
5. Duffy DM: Sclerosants: a comparative review. Dermatol Surg. 36 Suppl 2:1010-25, 2010
6. Lee BB et al: Management of arteriovenous malformations: a multidisciplinary approach. J Vasc Surg. 39(3):590-600, 2004

(Left) *A Gelfoam sheet is shown. Compress the sponge-like sheet to remove air. Rolling a syringe over the sheet is a good way to do this.* **(Right)** *The gelatin sponge sheet is then cut into strips. The strips may be rolled tightly into "torpedoes"* ↪*, which can be injected via syringes, sheaths, or guide catheters. Torpedoes are ideal embolics to occlude a proximal artery (e.g., traumatic bleed of an end artery) or percutaneous tract (e.g., transhepatic bleed related to access removal).*

Temporary Embolic, Step-By-Step Preparation (Gelfoam)

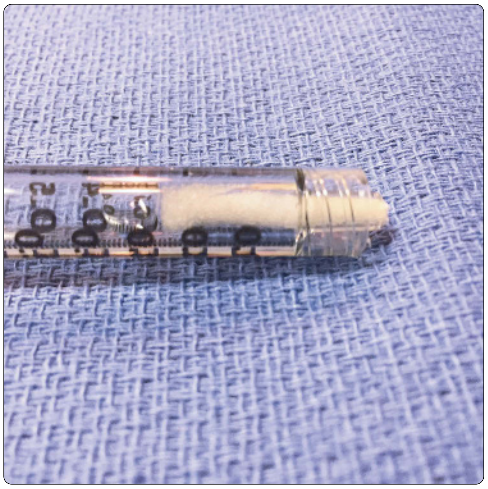


Temporary Embolic, Step-By-Step Preparation (Cut Into Strips)

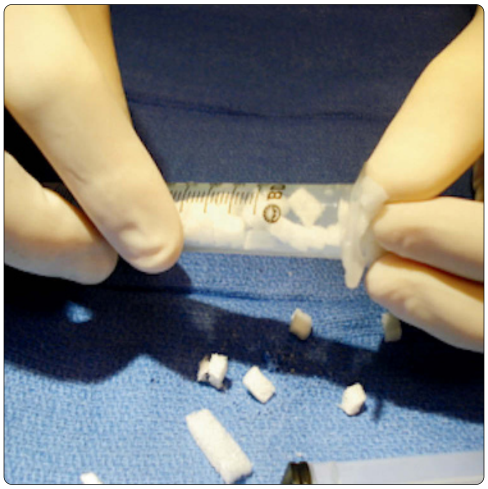


(Left) *The rolled torpedo can be inserted into the hub of a small-volume (1-3 cc) syringe, which has been filled with saline or contrast, and then injected into the desired location.* **(Right)** *Alternatively, a slurry can be created in order to embolize distal in a vessel, beyond what is possible with a torpedo. To make the slurry, cut the Gelfoam strips into smaller pieces and placed them into a 10-cc syringe. The plunger is then depressed to remove air.*

Temporary Embolic, Step-By-Step Preparation (Gelfoam Torpedo)

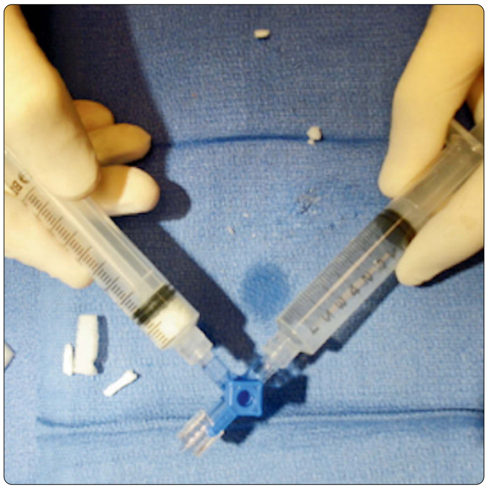


Temporary Embolic, Step-By-Step Preparation (Gelfoam Slurry)

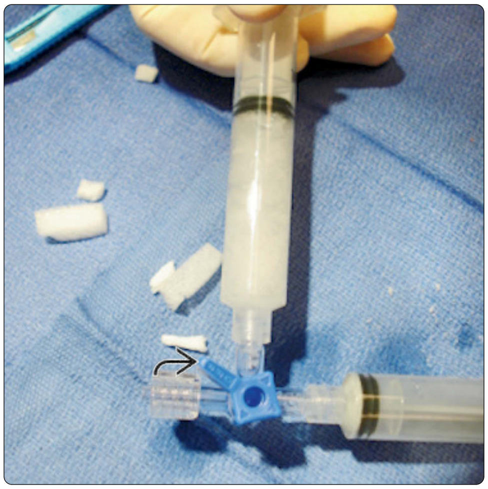


(Left) *The Gelfoam-filled syringe is attached to a 3-way stopcock and a contrast-filled syringe. Syringes are alternately depressed, mixing Gelfoam and contrast.* **(Right)** *The stopcock can be rotated slightly* ↪ *to decrease the lumen of the 3-way connector. As the solution is agitated and passed through the smaller lumen, Gelfoam particles are reduced in size, resulting in greater penetration of the slurry and reduced risk of catheter clogging during deployment.*

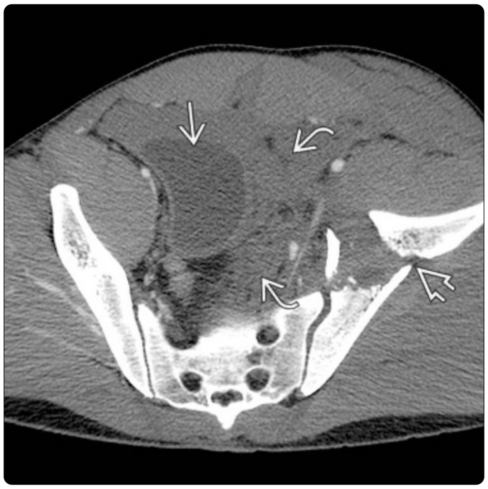
Temporary Embolic, Step-By-Step Preparation (Gelfoam Slurry)



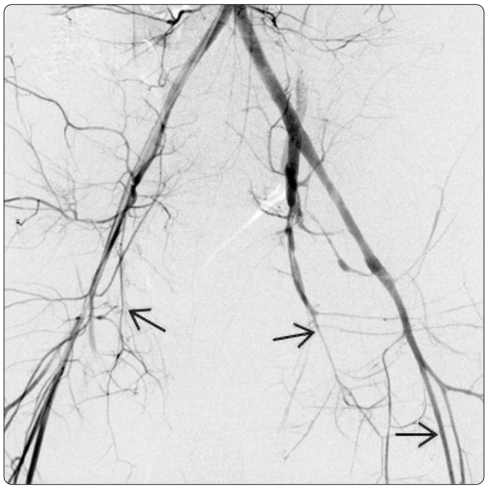
Temporary Embolic, Step-By-Step Preparation (Gelfoam Slurry)



Gelfoam Embolization of Pelvic Trauma (Diagnostic CECT)

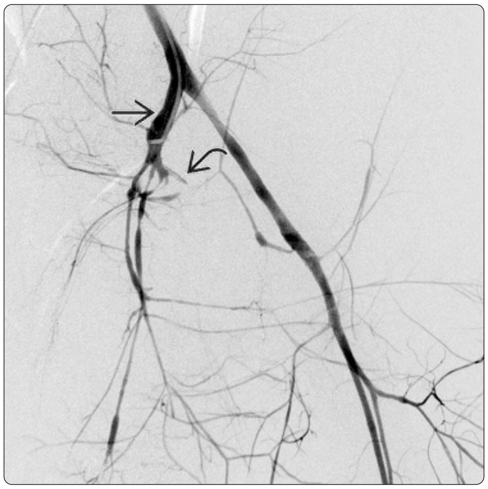


Gelfoam Embolization of Pelvic Trauma (Initial Pelvic Arteriogram)

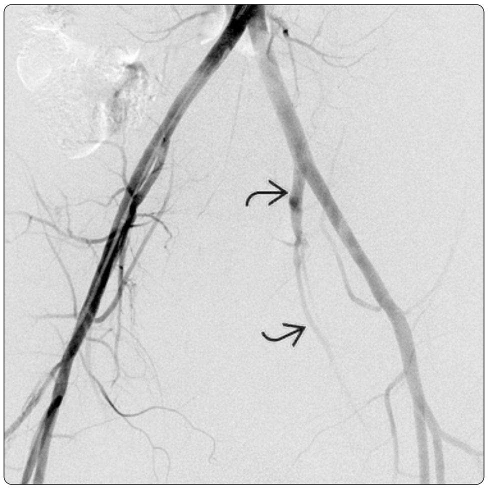


(Left) *A hypotensive patient who sustained blunt pelvic trauma has a displaced fracture of the left iliac wing* ⇨ *with a large pelvic hematoma* ➡ *displacing the urinary bladder* ↪. *The patient underwent emergent pelvic stabilization with external fixation.* **(Right)** *Following surgery, the patient remained hypotensive. Pelvic DSA shows marked and diffuse arterial vasoconstriction* ➡*, reflecting the hypotensive state. There is no extravasation demonstrated, however.*

Gelfoam Embolization of Pelvic Trauma (Internal Iliac Artery DSA)

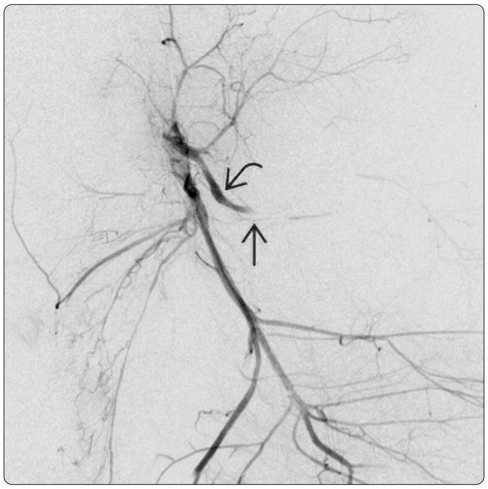


Gelfoam Embolization of Pelvic Trauma (Postembolization DSA)

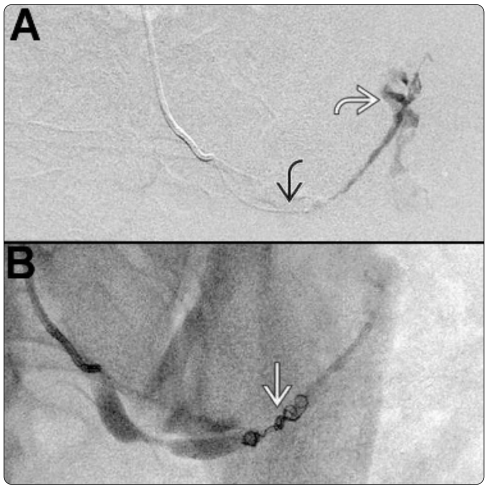


(Left) *Given the left-sided pelvic hematoma and iliac wing fracture, a left internal iliac artery* ➡ *DSA was obtained, revealing abrupt superior gluteal artery occlusion* ↪. **(Right)** *The left internal iliac artery was empirically embolized with a Gelfoam slurry with resultant prompt hemodynamic stabilization. Twelve hours later, the patient again became severely hypotensive. A repeat pelvic DSA (pictured) shows less vasoconstriction with perfusion of the previously embolized internal iliac artery branches* ↪.

Gelfoam Embolization of Pelvic Trauma (Repeat Internal Iliac Artery DSA)



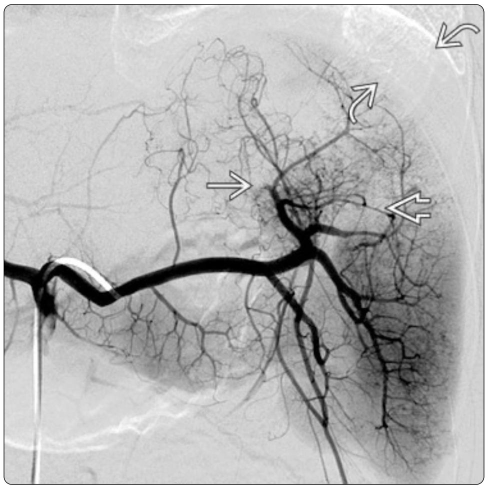
Gelfoam Embolization of Pelvic Trauma (Selective Coil Embolization)



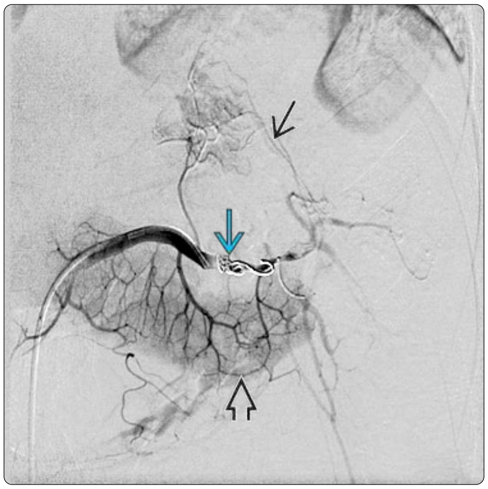
(Left) *A repeat left internal iliac artery DSA shows partial filling of the superior gluteal artery* ↪ *followed by abrupt termination* ➡. **(Right)** *(A) DSA obtained via a coaxial microcatheter* ↪ *placed in the superior gluteal artery revealed contrast extravasation* ⇨. *(B) Coil embolization* ➡ *of the injured artery was performed, and the patient again stabilized. While Gelfoam embolization initially controlled the hemorrhage, resultant vasodilatation allowed reperfusion and rebleeding.*

(Left) *A 33-year-old man who fell from a roof was hypotensive with grade 3 splenic injury at the time this DSA was obtained. Findings include abrupt cutoff of the superior splenic branch artery* →*, intraparenchymal defects* ⇨*, and separation of the spleen from the diaphragm* ↪ *consistent with subcapsular hematoma.* **(Right)** *Trauma service declined splenectomy. A DSA image shows coil embolization of the midsplenic artery* →*, allowing continued diminished flow to the spleen via short gastric* → *and pancreatic collaterals* ⇨*.*

Splenic Trauma (Diagnostic Arteriography)

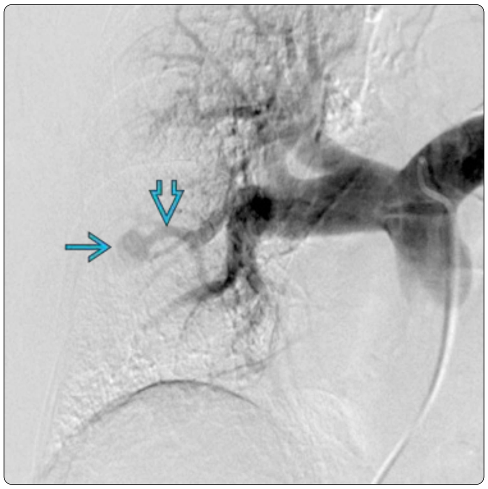


Splenic Trauma (Coil Embolization of Splenic Artery)

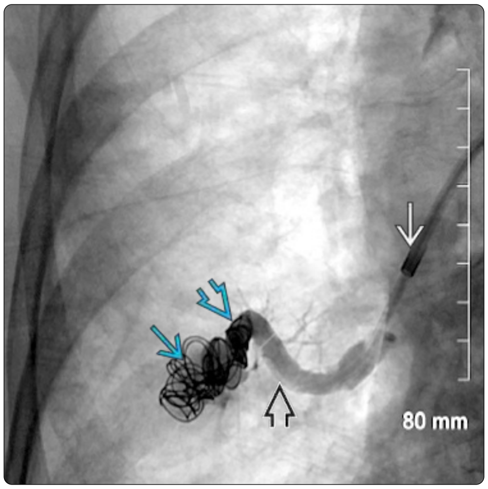


(Left) *A pulmonary arteriovenous malformation (PAVM)* → *is seen in the right lower lobe. It is simple in nature with a single feeding artery* ⇨*.* **(Right)** *A coaxial system of guide catheter* ⇨*, 5-Fr catheter* ⇨*, and microcatheter (not shown) were used to access and embolize the PAVM nidus* → *and feeding artery* ⇨*. Detachable coils are ideal in this situation because they can be positioned prior to release, limiting the risk that the coil will shunt through the nidus to systemic arteries.*

Pulmonary Arteriovenous Malformation (Diagnostic Pulmonary Arteriogram)

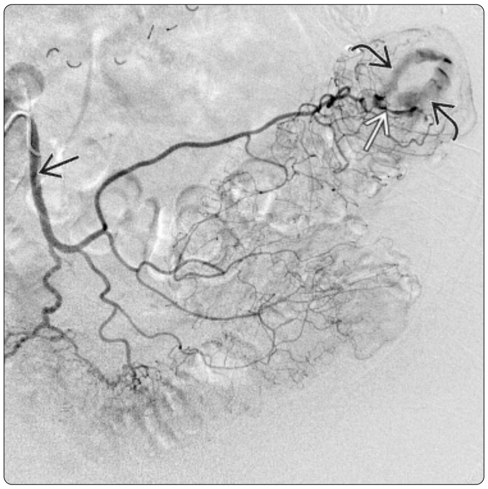


Pulmonary Arteriovenous Malformation (Post Coil Embolization)

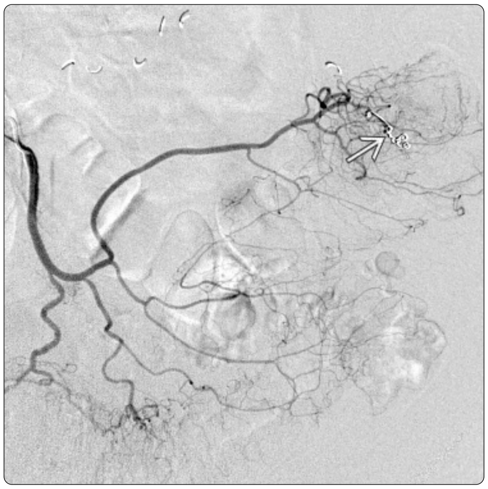


(Left) *DSA obtained in a patient with massive lower gastrointestinal hemorrhage shows inferior mesenteric artery* → *and contrast extravasation* ↪ *pooling in the splenic flexure, arising from a distal branch* → *of the left colic artery.* **(Right)** *A coaxial microcatheter was advanced into the left colic ascending branch artery, successfully allowing coil deployment to the arterial bleeding source* →*. The low risk of nontarget embolization favored use of inexpensive nondetachable coils over detachable coils.*

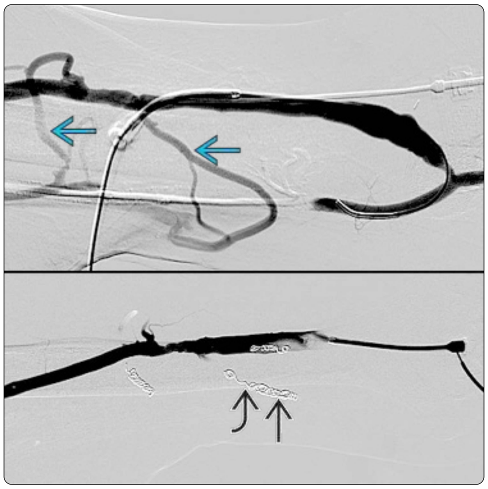
Lower Gastrointestinal Bleed (Diagnostic IMA DSA)



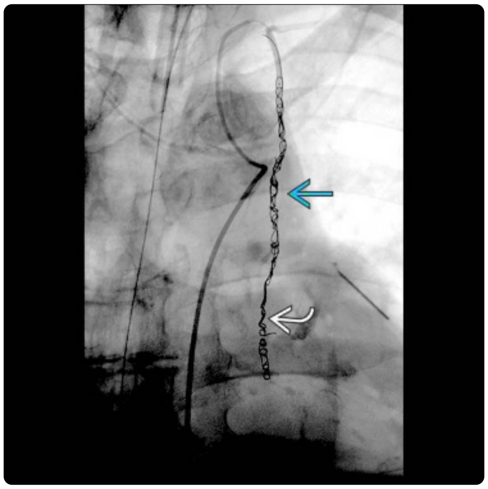
Lower Gastrointestinal Bleed (Post Coil Embolization)



Coil Embolization (Competing Veins of Hemodialysis Fistula)

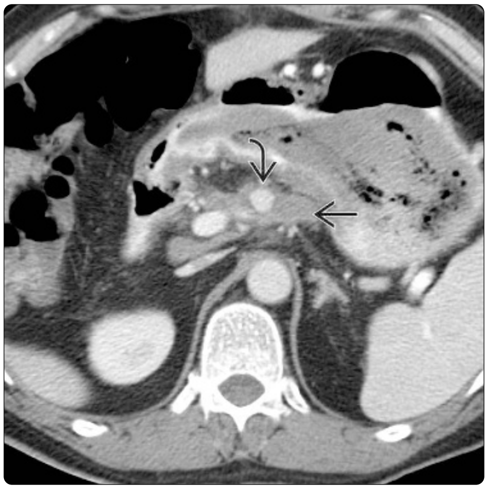


Coil Embolization Technique (Microcoil Embolization of LIMA)

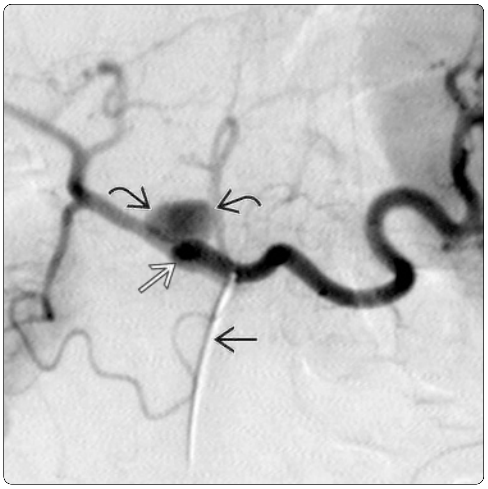


(Left) *(Top) Several competing veins → were prolonging dialysis sessions in a patient with left arm brachiocephalic hemodialysis fistula.(Bottom) Embolization of each competing vein occurred by securing deployment of a detachable coil → and following it with less expensive nondetachable coils ↪.* **(Right)** *A bleed of the left internal mammary artery was treated with coils above and below the injury →. When embolizing, it is important to achieve distal ➥ control to prevent retrograde perfusion of an injury.*

Stent-Assisted Coil Embolization (Initial CECT Evaluation)

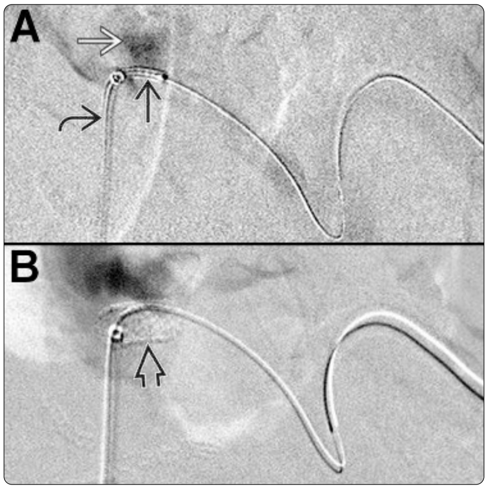


Stent-Assisted Coil Embolization (Selective Celiac Artery DSA)

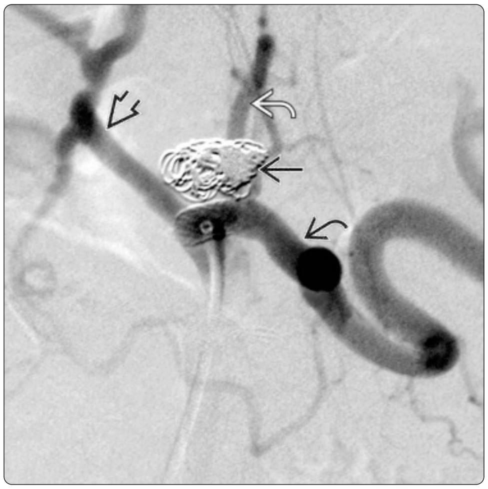


(Left) *A patient with known pancreatitis had acute onset gastrointestinal hemorrhage. CECT shows an arterial pseudoaneurysm (PSA) ↪ in the pancreas →, thought to result from exposure of the arterial wall to pancreatic enzymes.* **(Right)** *Celiac artery DSA via a Cobra catheter → confirms that the large PSA ↪ arises from the proximal splenic artery ➡. The PSA has a wide neck and is very near the splenic artery origin from the celiac trunk, making coil embolization difficult.*

Stent-Assisted Coil Embolization (Stent Placement at Aneurysm Base)

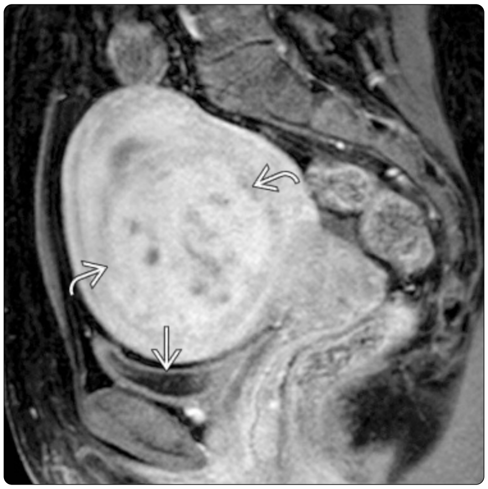


Stent-Assisted Coil Embolization (DSA Following Coil Embolization)

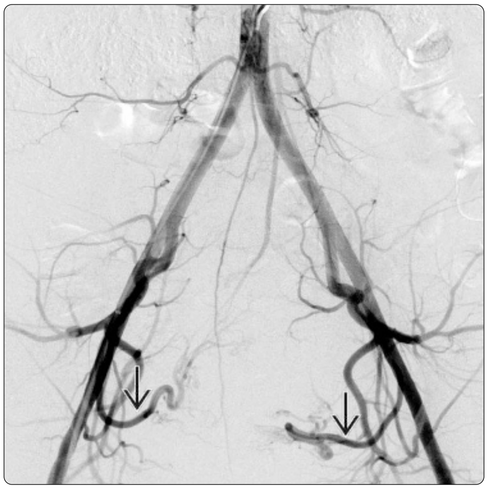


(Left) *Stent-assisted coil embolization was performed. (A) Via a guiding catheter ↪, a balloon-mounted stent → was placed across the neck of the PSA, in which contrast can be seen ➡. (B) The balloon was inflated, and the stent ⇨ deployed.* **(Right)** *A coaxial microcatheter was then advanced through the stent interstices into the PSA, where coils filled the PSA →. Following stent-assisted coil embolization, patency is preserved in the splenic ↪, left gastric ➥, and hepatic ⇨ arteries, but the PSA is occluded.*

(Left) *Sagittal T1WI C+ MR in a woman with menorrhagia, urinary frequency, and pelvic pressure shows a large enhancing uterine fibroid* ↷ *compressing the urinary bladder* ➡*. Uterine artery embolization was requested.* **(Right)** *A pelvic DSA shows hypertrophied uterine arteries* ⇨ *bilaterally, arising from the anterior divisions of the internal iliac arteries. Particle embolization is an ideal embolic to occlude the innumerable end-arterial branches supplying the fibroid tissue.*

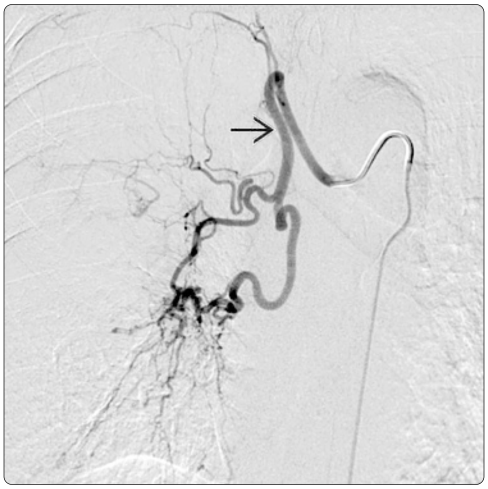


Particle Embolization (Uterine Fibroid)

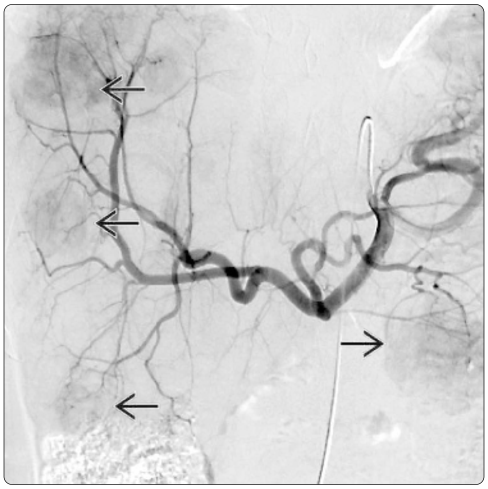


Particle Embolization (Initial Pelvic DSA)

(Left) *Bronchial DSA reveals a hypertrophied right bronchial artery* ⇨ *in a patient with cystic fibrosis and hemoptysis. Particle embolization attains distal arteriolar occlusion, while leaving the proximal artery patent for repeat embolization in the future (proximal coils would inhibit subsequent treatment).* **(Right)** *A celiac DSA highlights several enhancing hepatic lesions* ⇨*. Oncologic beads (chemotherapeutic-loaded drug-eluting beads or yttrium-loaded radioembolic beads) may offer treatment options.*

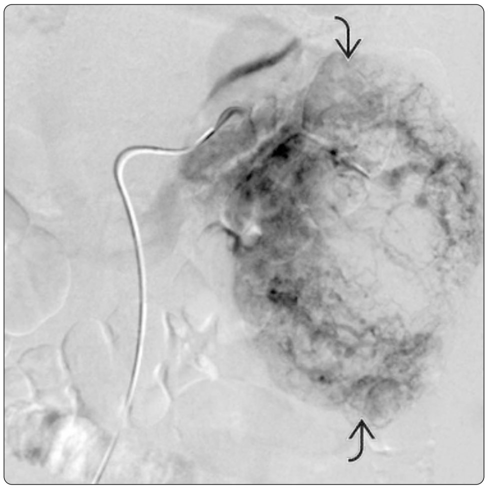


Particle Embolization (Hemoptysis)

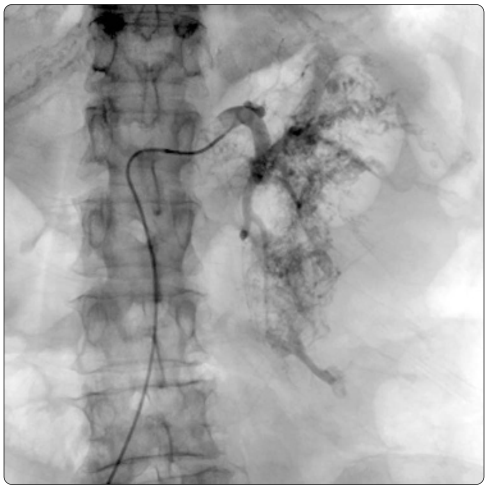


Oncologic Particles (Hepatic Metastatic Disease)

(Left) *A large angiomyolipoma (AML)* ↷ *is seen on left renal DSA before embolization.* **(Right)** *The same AML is shown on native angiogram during embolization. Several embolic agents could be used to embolize this AML (particles, liquid embolics, Gelfoam, or coils and plug occluders). Preoperatively before nephrectomy, inexpensive Gelfoam and coils may be appropriate. In a nonoperative situation, particles and liquids will have the best outcome, but be cautious of shunting suspected on preembolization image.*

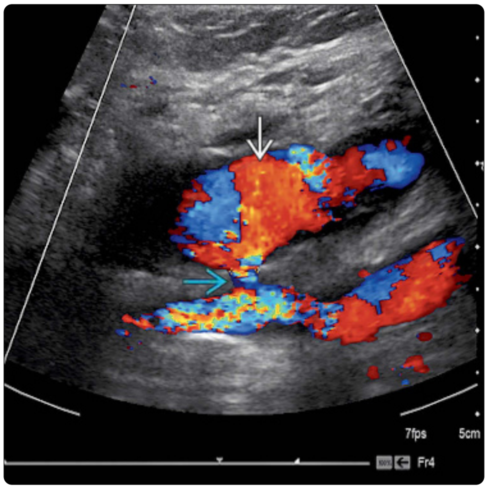


Angiomyolipoma (Preembolization)

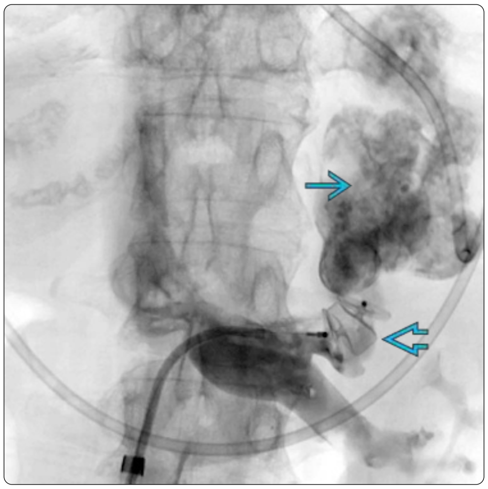


Angiomyolipoma (Mid Embolization)

Thrombin (Percutaneous Pseudoaneurysm Closure)

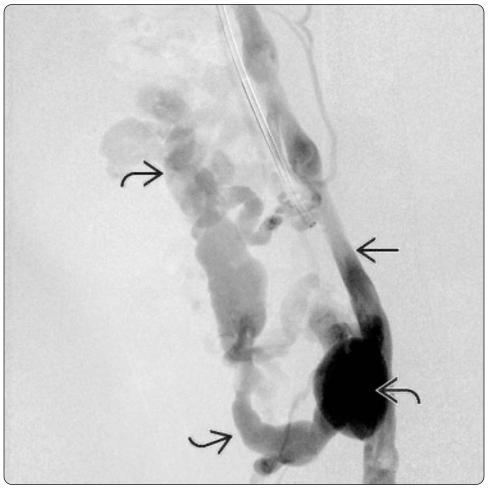


Sotradecol and Amplatzer (Balloon-Occluded Retrograde Transvenous Obliteration)

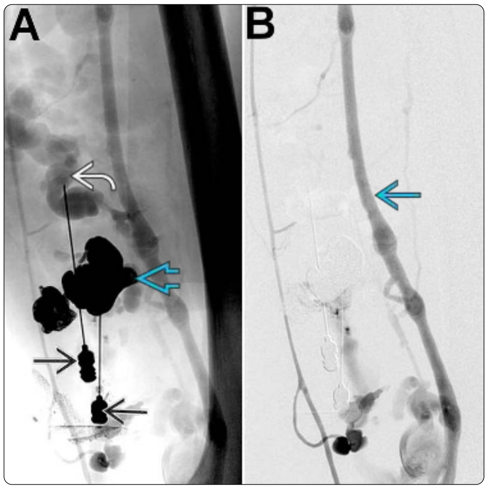


(Left) *A pseudoaneurysm (PSA)* ➡ *arises from a recent arterial access site. The PSA neck* ⇨ *is narrow but not very long. Due to the risk of potential distal arterial occlusion from thrombin, comfort with PSA thrombin-embolization is often operator specific.* **(Right)** *Sotradecol sclerotherapy foam* ⇨ *fills enlarged gastric varices, while an Amplatzer plug occluder* ⇨ *is positioned within an enlarged left adrenal vein. Together, these embolic agents should reduce the risk of further gastric variceal hemorrhage.*

Onyx Embolization of Venous Malformation (Ascending Venography)

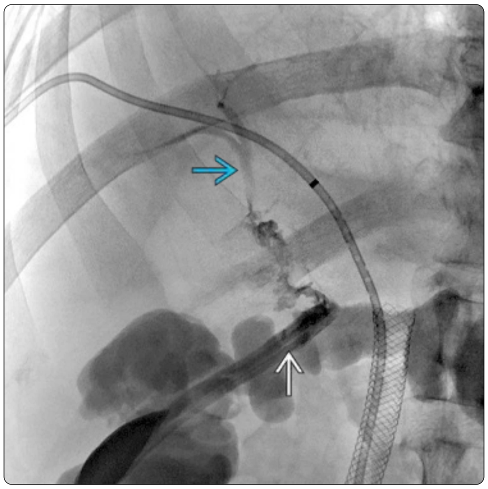


Onyx Embolization of Venous Malformation (Onyx Embolization)

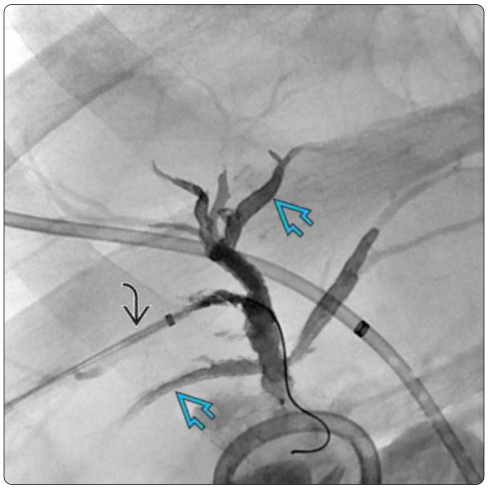


(Left) *DSA of the distal thigh shows an large venous malformation* ↷ *communicating with the femoral vein* ➡*.* **(Right)** *(A) Spinal needles* ➡ *were percutaneously advanced into deep venous "lakes"* ➡*, and Onyx* ⇨ *was slowly injected. (B) Following embolization, there is less filling of the malformation, but the femoral vein* ⇨ *remains patent. Additional treatments will be necessary.*

Glue and Onyx Embolization of Extrasegmental Bile Duct Leak (Diagnostic Sinogram)



Glue and Onyx Embolization of Extrasegmental Bile Duct Leak (During Embolization)



(Left) *Embolics have nonvascular utility [e.g., lymphocele sclerotherapy; extrasegmental bile duct leak (ESBDL) embolization]. Contrast injected through a surgical drain* ➡ *tracks into a biliary duct* ⇨*, inadvertently surgically excluded from the biliary system.* **(Right)** *Nonoperative options were sought. The ESBDL was accessed transhepatically* ↷ *and a coaxial microcatheter positioned within the ESBDL. Slow Onyx* ⇨ *injection, followed by rapid "glue" injection and access removal, successfully halted the leak.*

Stents: Vascular

KEY FACTS

TERMINOLOGY

- **Vascular stent**: Catheter-mounted metallic intravascular prosthesis; placed in diseased vessel
  - **Balloon-mounted**: Externally mounted on angioplasty balloon; inflate to deploy stent
  - **Self-expanding**: Sheathed in retractable delivery system; spontaneously expands
  - **Drug-eluting**: Stent coated with medication
  - **Biodegradable**: Polymer/metal alloy/drug coating
  - **Covered (stent-graft)**: Metallic stent combined with Dacron/ePTFE fabric graft

PREPROCEDURE

- Indications
  - Hemodynamically significant stenosis/obstruction
  - Adjunctive therapy to angioplasty; suboptimal angioplasty result
  - Vascular injury/active bleed
  - Adjunct to other therapy: Stent-assisted coiling

PROCEDURE

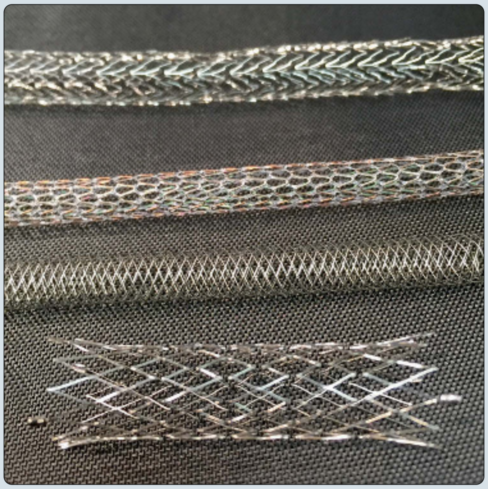
- Obtain vascular access
- Position catheter proximal to stenosis/occlusion
  - Administer heparin bolus prior to crossing lesion
  - Gently advance guidewire across lesion
- Advance selective catheter over wire, across lesion
  - Once catheter beyond lesion, place stiff guidewire
  - Consider angioplasty prior to stenting
- Replace catheter with stent delivery system
- Position stent appropriately for target lesion
  - Angiographically confirm before deploying
- Deploy stent under continuous observation
- Angioplasty afterwards if necessary

POST PROCEDURE

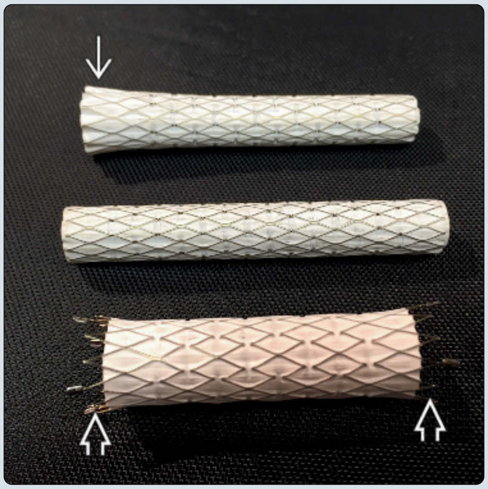
- Arterial stent: Initiate antiplatelet regimen
- Venous stent: Consider systemic anticoagulation if concomitant thrombosis

(Left) *A variety of self-expanding bare metal stents are shown, including (from top to bottom) Abbott Absolute Pro, Gore Tigris, Abbott Supera, and Bard E-Luminexx. Note design differences between open cell (e.g., E-Luminexx), closed cell (e.g., Tigris), and interwoven nitinol (e.g., Supera) stents.* **(Right)** *A variety of covered stents are shown, including (from top to bottom) Bard Flair (flared/trumpeted configuration →), Flair (straight configuration), and Fluency (with uncovered bare metal ends ⇨) stent-grafts.*

Bare Metal Stents

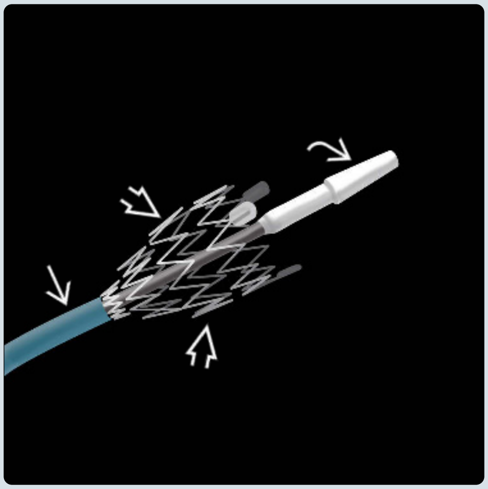


Covered Stents (Stent-Grafts)

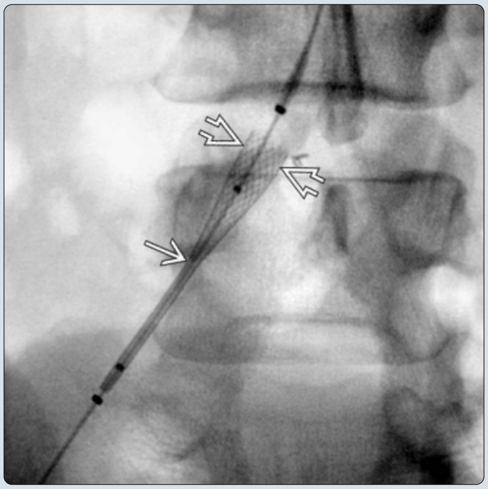


(Left) *Photograph of a self-expanding stent shows the tapered catheter tip ↪, the partially expanded stent ⇨, and the retractable sheath →, which constrains the stent until it is unsheathed within the target vessel.* **(Right)** *Fluoroscopic image shows a self-expanding stent ⇨ that is partially deployed, with a transition point → where the stent has not yet been unsheathed. Postdeployment angioplasty is often necessary with self-expanding stents.*

Stent Deployment (Photographic Appearance)



Stent Deployment (Fluoroscopic Appearance)



Stents: Vascular

TERMINOLOGY

Synonyms

- Vascular endoprosthesis

Definitions

- Vascular stent: Catheter-mounted metallic intravascular prosthesis
  - Provides intravascular scaffold
    - Allows for endothelialization
      - Endothelial cells migrate into stent
      - Leads to in-stent restenosis
    - Provides intravascular rigidity
      - Compresses atheroma, dissection flaps
      - Resists elastic recoil
  - Placed in diseased vascular structures
    - Arteries
    - Pulmonary arteries
    - Veins
    - Portal veins
  - Various indications
    - Recanalization of luminal stenosis/occlusion, including
      - Arterial atherosclerotic plaque [e.g., peripheral arterial disease (PAD), chronic mesenteric ischemia]
      - Venous extrinsic compression (e.g., May-Thurner syndrome)
      - Intimal hyperplasia (e.g., hemodialysis access outflow narrowing)
    - Aneurysm/pseudoaneurysm exclusion
    - Traumatic/iatrogenic arterial perforation
    - Arteriovenous (AV) communications
    - Stent-assisted coil embolization
- Various delivery systems/calibers
  - 0.035" delivery system
  - 0.014"/0.018" delivery system
- Vascular stent designs
  - **Closed-cell**: Every stent segment connected by link
    - Less flexible, may develop kinks
    - Occasional incomplete expansion
    - Better radial force/intravascular scaffolding
  - **Open-cell**: Some stent segment connections absent
    - Conforms to angled vessels/tortuous anatomy
    - Less radial force/intravascular scaffolding
- Vascular stent technologies
  - **Balloon-mounted**: Externally mounted on percutaneous transluminal angioplasty (PTA) balloon
    - Risk of dislodgement; prevent by introducing through guiding catheter/sheath
      - Balloon inflation to deploy stent
      - Somewhat variable diameter range
      - More rigid stent design
    - Conforms poorly to changing vessel diameters
    - Balloon-mounted stent delivery designs
      - **Over-the-wire (OTW)**: Central lumen for guidewire access/contrast injection, small parallel lumen for balloon inflation/deflation during stent deployment
      - **Rapid-exchange (monorail)**: Guidewire passes through balloon, exits catheter proximal to balloon, runs alongside catheter shaft
  - **Self-expanding**: Sheathed in retractable delivery system; spontaneously expands after retraction
    - Most frequently constructed from nitinol
      - Alloy regains original shape when no longer compressed/constrained
    - Requires appropriate oversizing to achieve secure intravascular fixation
    - Typically more flexible
    - Conforms to changing vessel diameters
  - **Drug-eluting**: Stent coated with medication (e.g., paclitaxel)
    - Delivers antiproliferative drug to vessel surface
      - Local drug prevents in-stent stenosis
      - Drug reduces neointimal proliferation
  - **Biodegradable**: Made of polymers/metal alloys ± drug coating
    - Scaffold artery, allows natural healing to occur
      - Subsequently biodegrades; may deliver sustained drug release as degradation proceeds
    - Several biodegradable stents in clinical trials
      - Many more at preclinical stage of development
  - **Radioactive**: Catheter-based intravascular brachytherapy, mainly from gamma/beta sources
    - Majority of studies relate to coronary arteries
    - High restenosis incidence at stent margins
    - Ongoing investigational studies
  - **Covered (stent-graft)**: Metallic intravascular stent combined with fabric graft of either Dacron or expanded polytetrafluoroethylene (ePTFE)
    - Courses inside vascular lumen; redirects blood flow through device rather than native vessel
      - Radial force of metallic stent secures graft
      - Catheter-mounted delivery system
    - 3 FDA-approved peripheral stent grafts
      - **Atrium iCAST** (Atrium Medical; Hudson, NH): Balloon-mounted expandable ePTFE stent graft
      - **Bard Fluency** (Bard; Tempe, AZ): Self-expanding nitinol stent encapsulated with ePTFE; retractable delivery system
      - **Gore Viabahn** (WL Gore; Newark, DE): Inner ePTFE fabric graft attached to external self-expanding nitinol stent

PREPROCEDURE

Indications

- Hemodynamically significant stenosis or obstruction
  - Primary therapy
    - Carotid artery stenoses
    - Orificial stenoses (e.g., renal arteries)
  - Adjunctive therapy to angioplasty; suboptimal angioplasty result
    - Extensive length of irregular lumen following recanalization of long segment occlusion
    - Elastic recoil
    - Flow-limiting dissection after PTA
- Restore integrity to diseased arterial segment
  - Covered stents (stent-grafts)
    - Provide intravascular conduit, excluding diseased segment by attaching to adjacent healthy tissue

            - Aneurysm exclusion (e.g., popliteal artery aneurysm)
            - Traumatic arterial perforation
            - Arteriovenous communications
- Adjunct to other therapy
    - Stent-assisted aneurysm/pseudoaneurysm coiling/exclusion

Getting Started

- Things to check
    - Clinical history and physical examination
        - Emphasis on risk factors for PAD
            - Should also evaluate carotid/coronary arteries; high incidence of concurrent disease
            - Smoking cessation key for preventing/decreasing disease recurrence/progression
        - Detailed pulse examination/Doppler evaluation
            - Document ankle-brachial index before/after stenting for lower extremity lesions
        - Current medications
            - Any anticoagulants, antiplatelet agents, oral hypoglycemic agents, antihypertensives
    - Allergies
    - Laboratory parameters
        - Electrolytes, glomerular filtration rate (eGFR)
            - Prefer normal Cr; eGFR > 60
        - Complete blood count (CBC) not routinely recommended
            - Platelet count > 50,000/μL if evaluated
        - Coagulation profile
            - International normalized ratio (INR) ≤ 1.5 recommended
            - Normal partial thromboplastin time (PTT) recommended for patient receiving IV heparin
    - Limit oral intake: NPO for 8° prior to procedure
        - If moderate sedation/general anesthesia planned
        - Take any oral medications with water sip
- Medications
    - Heparin
        - Various intraprocedural administration regimens
            - Bolus dose of 2,500-5,000 U; followed by infusion of 1,000 U/hr
            - Loading dose of 50-100 U/kg; followed by continuous infusion of 15-25 U/kg/hr
        - Usually administered prior to crossing lesion
        - May sometimes be continued post procedure
    - Antibiotics
        - Prophylactic antibiotics not currently recommended in routine arterial stent placement
        - Consider antibiotics for patients at high risk for infection (i.e., cases of repeat intervention within 7 days, prolonged indwelling arterial sheath, prolonged procedure duration)
            - 1 g cefazolin IV
            - If patient allergic to penicillin, consider using vancomycin or clindamycin
    - Vasodilator (e.g., nitroglycerin)
        - Typical bolus dose of 100 μg nitroglycerin
        - Prevents/treats catheter-induced vasospasm
    - Clopidogrel (typically only with arterial stents)
        - May electively give loading dose preprocedure
            - 300 mg minimum loading dose
        - Continue maintenance dose post procedure
            - 75 mg daily dose for 4-6 weeks minimum
- Equipment list
    - Vascular access sheath
        - Sheath size depends on stent/catheter size
        - Permits catheter exchanges as necessary
            - Reduces local complications at access site
    - Guiding catheter/sheath (typically 5-6 Fr)
        - Allows coaxial injection around stent delivery system/guidewire/angioplasty balloon
        - Use to precisely localize stent position
    - Selective catheter and guidewire
        - Configuration depends upon target vessel/lesion
        - Hydrophilic guidewire often used to cross lesion
        - Stiff guidewire: Provides stability across lesion during stent delivery/deployment (e.g., Amplatz, McNamara, Lunderquist, Rosen)
    - Stent and stent delivery system: Dependent on target location, size, accessibility
    - Calibrated insufflator device
        - For precise atmospheric pressure inflation of balloon-mounted stents and angioplasty
    - Angioplasty balloon catheter
        - May predilate lesion prior to stent placement
            - May be necessary before balloon-mounted stent
        - May postdilate following stent placement
            - May be necessary following self-expanding stent

PROCEDURE

Patient Position/Location

- Best procedure approach
    - Arterial stent
        - Usually retrograde common femoral artery access for pelvic, contralateral lower extremity, renal, visceral artery, great vessel lesions
        - Brachial/radial access for some upper extremity, some renal/visceral lesions (e.g., superior mesenteric artery)
        - Antegrade common femoral artery access may be used for ipsilateral lower extremity lesions
    - Venous stent
        - Common femoral vein for pelvis, IVC, lower extremities; sometimes for SVC/central veins
        - Jugular vein access for some venous stenoses (e.g., SVC, hepatic veins, TIPS stenosis)
        - Dialysis-related venous stenoses (peripheral and central) usually accessed through fistula/graft

Procedure Steps

- **General**
    - Obtain vascular access
    - Introduce vascular access sheath over guidewire
    - Introduce appropriate diagnostic catheter
        - Obtain diagnostic angiogram; evaluate target lesion
    - Consider coaxial system (often used for target arteries such as carotid, renal, mesenteric)
        - Advance guiding catheter/sheath (typically 5 or 6 Fr)
            - Allows injection through guiding sheath/catheter around inner catheter/stent/wire
            - Precisely localizes lesion during stent deployment

    - Introduce selective catheter (typically 4 or 5 Fr) coaxially through guiding catheter/sheath
    - Determine stent type, size, and system
      - Balloon-mounted or self-expanding rapid-exchange stents typically use smaller caliber system (0.014" or 0.018" guidewire)
      - Self-expanding stents for larger lesions or covered stent-grafts typically use larger caliber system (0.018" guidewire)
  - Administer heparin bolus prior to crossing lesion
    - 2,500-5,000 unit bolus (IV or IA)
  - Consider antibiotics for high-risk patients
  - Advance selective catheter over wire across lesion, remove guidewire from catheter, inject contrast to confirm catheter tip position
  - Once catheter tip is beyond lesion, exchange for stiff guidewire
  - **Caution**: Maintain guidewire access across lesion at all times until post stent deployment DSA complete and reviewed
  - Consider angioplasty predilation prior to stenting
  - Advance stent into position for deployment
    - Look for radiopaque markers on stent delivery system catheter
    - Consider utilizing live image-subtraction (e.g., Roadmap) technology during stent deployment
    - Stent should bridge between healthy vascular segments adjacent to diseased segment
  - Carefully deploy stent
    - Watch monitors throughout deployment
    - Hold deployment system in-line with access; wire straight and taut
    - Firmly set feet; consider pinning hand to stable surface (e.g., table) during deployment (of self-expanding stent)
      - When both hands, free-floating stent more likely to malposition during deployment
    - Assistant can hold sheath in place during deployment (of self-expanding stent)
  - Remove stent delivery system
    - Maintain guidewire access across stented segment
  - Inject guiding catheter/sheath or access sheath
    - Confirm satisfactory stent position/expansion
    - Determine if any additional treatment necessary
      - If additional stent(s) required, overlap by 1 cm
  - If stent position/diameter satisfactory
    - Obtain DSA images of vasculature distal to stent
      - Document runoff quality/no complications
    - Remove guidewire
    - Remove access/guiding sheath
    - Secure hemostasis at access site
  - **If balloon-mounted stent**
    - Stent externally mounted on balloon; risk of stent dislodgement if crossing tight stenosis
      - Prevent dislodgement by PTA before advancing stent across stenosis
      - May also prevent dislodgement by first crossing stenosis with guiding catheter/sheath; positioning stent, and then withdrawing catheter/sheath to expose stent
    - Use calibrated insufflator device; inflate to appropriate atmospheric pressure
      - Balloon inflation deploys stent
    - Visualize completely deflated balloon
      - Remove balloon from within stent; leave guidewire in place
    - Inject guiding catheter/sheath or access sheath
      - Confirm satisfactory stent position/expansion
  - **If self-expanding stent**
    - Stent sheathed in retractable delivery system
      - Retract delivery catheter sheath to deploy stent
    - Carefully maintain stent position during deployment; monitor fluoroscopically
      - Tendency for stent position to change when retracting delivery system; adjust accordingly
      - Some stents shorten considerably during deployment
    - After stent deployment, remove delivery system
    - Postdeployment angioplasty often necessary
      - Base balloon size on target vessel diameter
- **If crossing stenotic lesion**
  - Gently advance guidewire across stenosis
    - Monitor fluoroscopically while crossing lesion
      - May use roadmap when crossing lesion
    - Imperative to avoid vessel dissection
    - If resistance to guidewire passage
      - **Caution**: Do not continue to advance guidewire; may cause dissection, vessel perforation
      - Retract wire; reorient catheter; readvance wire
      - Consider different catheter shape, guidewire
    - Keep catheter parallel to vessel centerline
      - Direct guidewire through stenotic channel
      - Advance catheter through lesion over guidewire
      - Position catheter distal to lesion; remove wire
      - Inject contrast; confirm catheter tip position
    - Follow sequence for stent placement
- **If venous stent**
  - Lesion location determines stent appropriateness: Repeated venous angioplasties may be more appropriate for maintaining long-term patency
    - Thoracic inlet: Venous stents may be contraindicated due to deformity/fracture from musculoskeletal structures
    - May-Thurner: Residual extrinsic compression may be angiographically subtle but is often apparent with intravascular US (IVUS), suggesting stenting often appropriate
    - Central veins: Some studies suggest increased patency following PTA vs. stenting

Alternative Procedures/Therapies

- Radiologic
  - Angioplasty
  - Atherectomy
- Surgical
  - Vascular bypass surgery
  - Endarterectomy

POST PROCEDURE

Things to Do

- Arterial stent
  - Initiate antiplatelet regimen after procedure
    - Clopidogrel 75 mg daily for 4-6 weeks
    - Aspirin 81 mg daily, indefinitely
- Venous stent
  - Consider systemic anticoagulation if stent placed following thrombolysis
- Clinically follow patient
  - Depending on lesion treated may obtain
    - Noninvasive arterial studies
      - Impedance plethysmography
      - Pulse volume recording
      - Segmental limb pressures; ankle-brachial index
    - Duplex Doppler evaluation
    - CT angiography
- Encourage lifestyle modification

OUTCOMES

Complications

- Most feared complication(s)
  - Vessel rupture
    - May be caused by stent oversizing/aggressive PTA
      - Always maintain guidewire access across lesion until posttreatment DSA performed and reviewed
    - Stabilize by inflating balloon to tamponade
    - Requires covered stent or surgical repair
  - Other vascular injury
    - Dissection, perforation
- Immediate/periprocedural complication(s)
  - Access site complications: Hematoma, pseudoaneurysm, AV fistula
  - Stent migration: Stent too small
    - If still over wire, may tack down with larger stent
  - Contrast hypersensitivity reaction
  - Contrast-induced nephropathy
- Delayed complication(s)
  - In-stent restenosis (ISR)
  - Stent fracture
    - Usually at site of repeated extrinsic compression (e.g., subclavian vein)
    - Or sites of repeated torsion, compression, flexion (e.g., superficial femoral artery)
  - Immediate/delayed arterial stent thrombosis (2-10%)
    - Minimize with antiplatelet/anticoagulation agents
- Other complications
  - Distal embolization of plaque (2-8% incidence) or thrombus
    - Usually asymptomatic microscopic debris
    - Macroscopic embolization may occur

Expected Outcomes

- High initial technical success rate
  - Initial technical success depends on
    - Anatomic location of lesion (e.g., iliac, femoral)
      - Less optimal long-term results in highly mobile areas (e.g., common femoral, popliteal); stent fatigue/fractures occur from excessive motion
    - Length of occlusion/stenosis (arterial: TASC classification)
    - Lesion morphology (e.g., eccentric, calcified)
  - Long-term technical and clinical results depend on
    - Same factors as for initial success rates
    - Quality of downstream flow
    - Relevant risk factors
      - Tobacco use, diabetes, hyperlipidemia
      - Hypercoagulability
    - Neointimal hyperplasia
- ISR
  - Variable patency rates in short and long term
    - PTA of ISR has high immediate procedural success, discouraging medium and long-term patency
      - PTA of ISR with drug-eluting balloon has > 90% patency at 1 year
    - If ISR is related to stent-fracture, overstenting with covered stent or drug-eluting stent is usually appropriate

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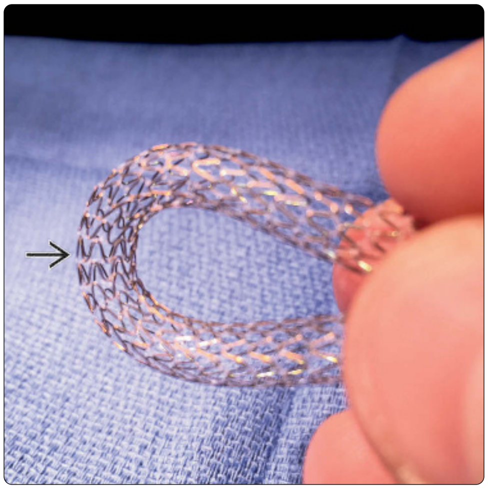
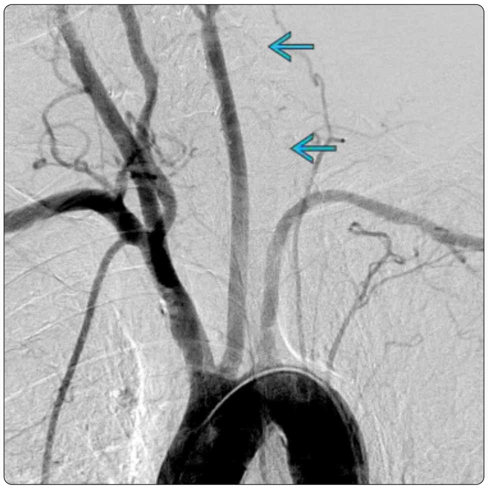
Bare Metal Stents

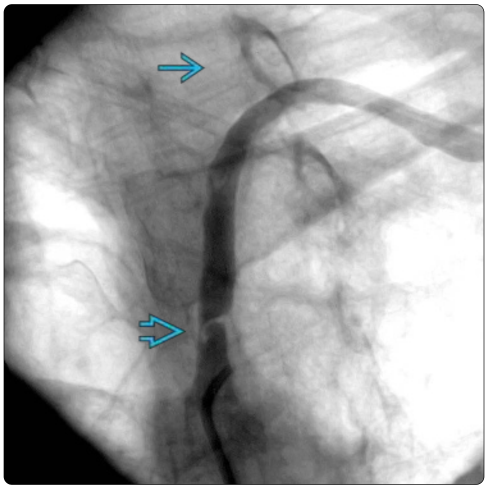


Subclavian Steal (Aortogram)

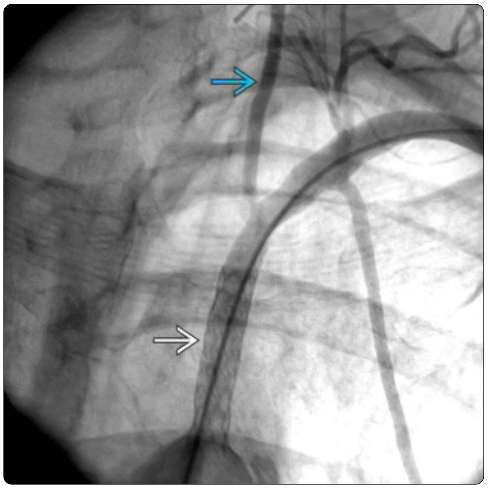


(Left) *Open-cell BMS are inherently more flexible, but with less scaffolding uniformity. Closed-cell BMS inherently have less flexion and conformability, but increased scaffolding uniformity. Additionally, at a point of convex angulation →, open-cell struts can extend into and beyond the intima, whereas newer closed-cell BMS designs (e.g., Gore Tigris shown) strive to limit strut extension and improve flexibility.* **(Right)** *Aortogram reveals lack of contrast-filling in the left vertebral artery →.*

Subclavian Steal (Left Subclavian Arteriogram)

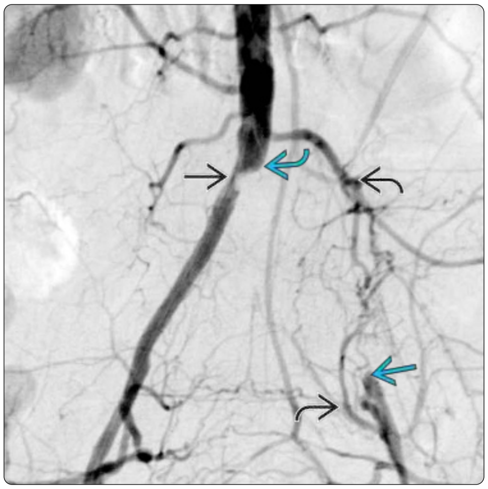


Subclavian Steal (Post Stent Deployment)

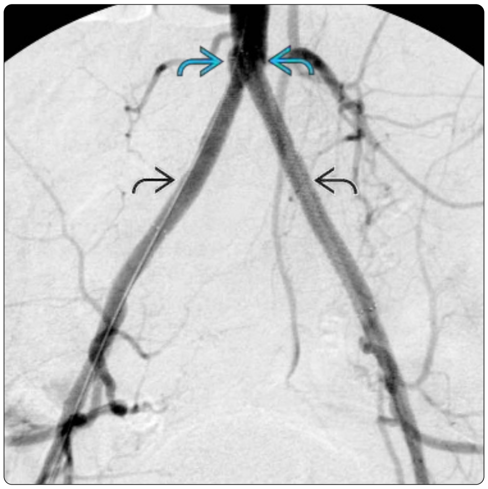


(Left) *Selective arteriogram of the left subclavian artery reveals a partially obstructive linear defect ⇨ near the subclavian artery origin. Again, filling of the vertebral artery is absent →.* **(Right)** *Following placement of a BMS ➡, normal antegrade flow is restored to the left subclavian and vertebral arteries →. A BMS was used in part due to concerns that the vertebral artery origin, which was not well visualized, could be inadvertently jailed during stent placement. The patient's symptoms resolved completely.*

Bilateral Iliac Artery Stents (Diagnostic Arteriogram)



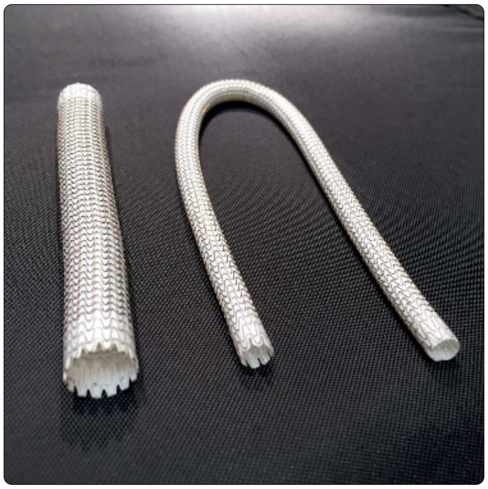
Bilateral Iliac Artery Stents (Postdeployment)



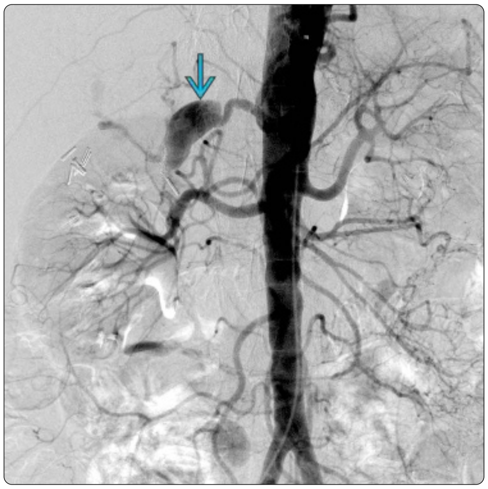
(Left) *Pelvic DSA shows a left common iliac artery occlusion extending from the aortic bifurcation ↪ to the external iliac artery →, which is reconstituted via iliolumbar collaterals ↪. Severe stenosis → of the proximal right common iliac artery is also present.* **(Right)** *Using bilateral femoral access, both the occlusion and stenosis were crossed, and bilateral stents ↪ were deployed simultaneously in a configuration known as "kissing" ↪ stents. This provides scaffolding for both arteries at the bifurcation.*

(Left) *Shown is an example of a covered stent (Gore Viabahn) comprised of a polytetrafluoroethylene (ePTFE) liner attached to an external nitinol stent structure.* **(Right)** *A 52-year-old woman presented with sudden-onset abdominal pain. Abdominal CECT (not shown) revealed a large aneurysm → involving the common, proper, and right hepatic artery, best seen on this DSA aortogram. The aneurysm was felt to be at risk of eminent rupture.*

Covered Stents (Stent-Grafts)

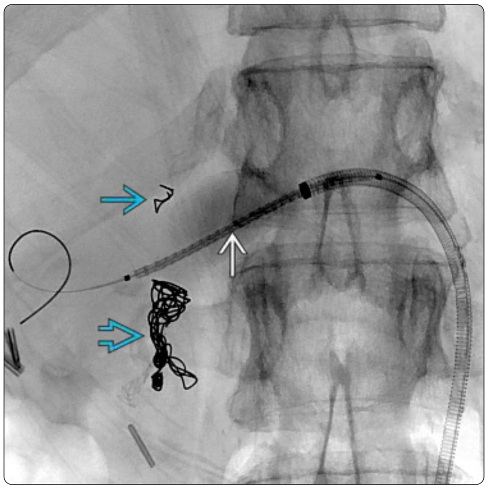


Hepatic Artery Aneurysm (Aortogram)

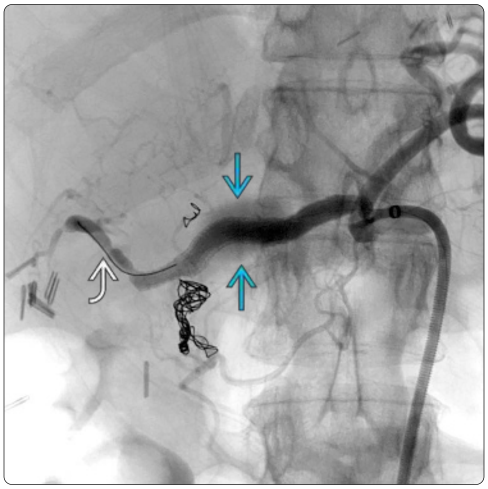


(Left) *After surgery failed to treat, it was decided that the aneurysm would be excluded with a covered stent (off-label usage). Prior to deployment of the stent ➡, the left hepatic → and gastroduodenal → arteries were embolized to prevent type II endoleak. Contrast injected through the guide sheath outlined the aneurysm during stent deployment.* **(Right)** *Following stent placement, trapped contrast is seen within the aneurysm →. The right hepatic artery remains patent, albeit with transient spasm ↪. No hepatic injury occurred.*

Hepatic Artery Aneurysm (Stent Deployment)

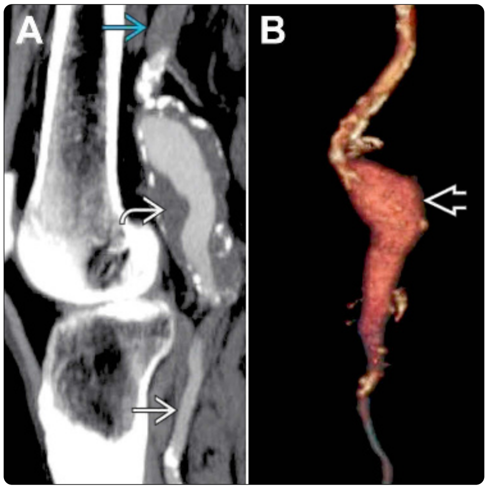


Hepatic Artery Aneurysm (Aortogram)

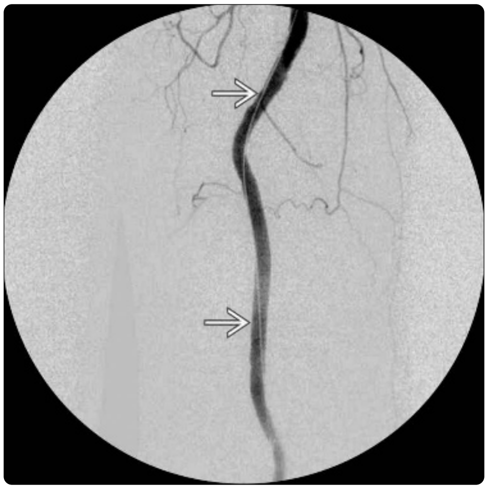


(Left) *(A) Sagittal CECT and (B) 3D reformation show a popliteal artery aneurysm ➡ containing laminar thrombus ↪. The artery is normal in caliber proximal → and distal ➡ to the aneurysm. Healthy vascular tissue adjacent to the diseased segment is critical to covered stent exclusion of an aneurysm.* **(Right)** *After covered-stent placement and angioplasty, the aneurysm no longer opacifies. The stent-graft ➡ excludes the aneurysm from circulation, eliminating the potential for aneurysm thrombosis or distal embolization.*

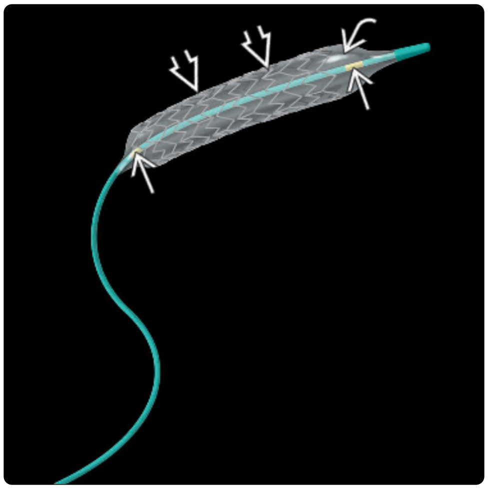
Popliteal Artery Aneurysm (CECT With 3D Post-Processing)



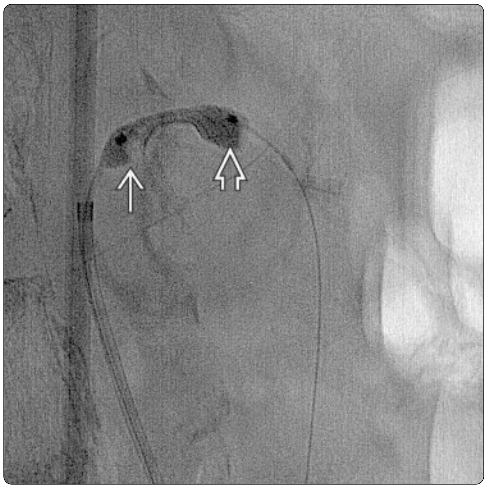
Popliteal Artery Aneurysm (Postexclusion Angiogram)



Balloon-Mounted Stent

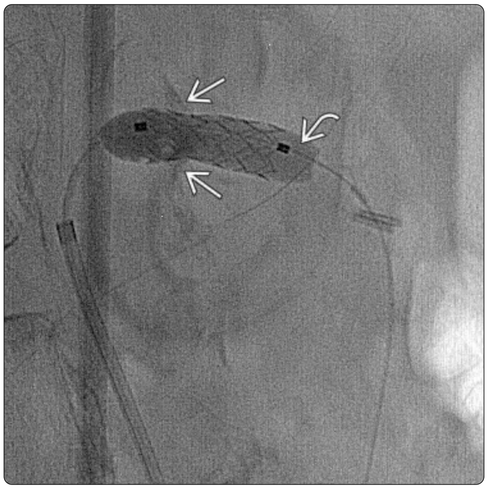


SMA Balloon-Mounted Stent Deployment (Stent Positioning, Balloon Partially Inflated)

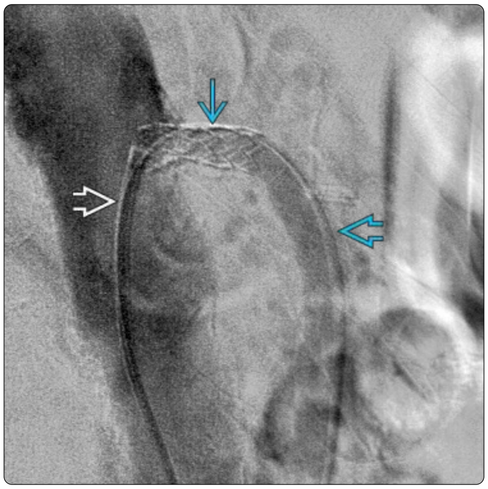


(Left) *Graphic of a balloon-mounted stent shows that the balloon ↪ has been inflated, thereby expanding the stent ⇨. There are proximal and distal radiopaque markers → that denote the stent margins for precise deployment.* **(Right)** *Cross-table lateral imaging shows a balloon-mounted stent as it is deployed at the origin of a SMA. Note that the balloon expands first at the proximal → and distal ⇨ end of the stent, preventing the stent from migrating as it is deployed.*

SMA Balloon-Mounted Stent Deployment (Balloon Fully Inflated)

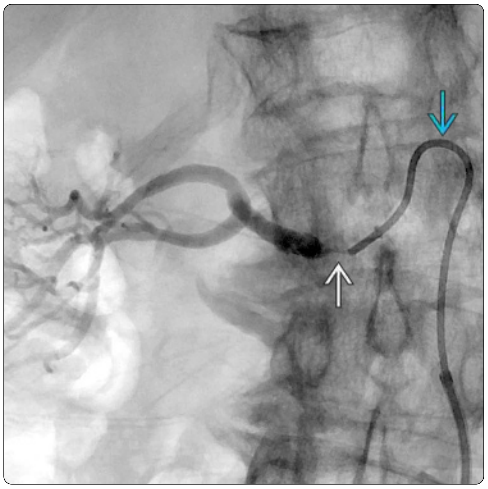


SMA Balloon-Mounted Stent Deployment (Postdeployment Angiogram)

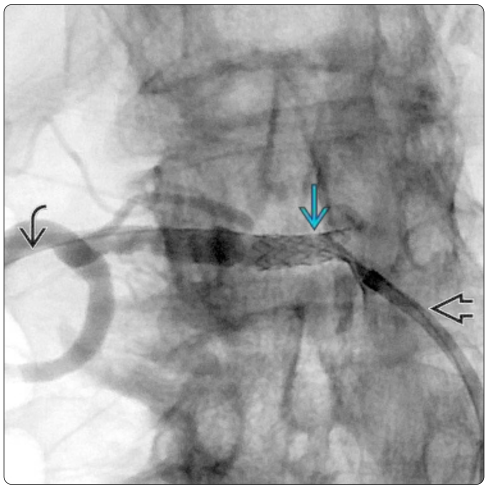


(Left) *The pressure of the fully dilated balloon ↪ is needed to dilate the atherosclerotic plaque →, which is limiting flow through the SMA. Once dilated, the high intrinsic radial force of the stent maintains patency of the vessel.* **(Right)** *Once the balloon is removed, contrast is injected through the guide sheath ⇨. The stent → is well positioned, extending slightly back into the aorta. Adequate antegrade flow through the SMA ⇨ is restored. Note the absence of celiac arterial flow just superior to the SMA, suggesting celiac occlusion.*

Renal Artery Balloon-Mounted Stent Deployment (Diagnostic Arteriogram)

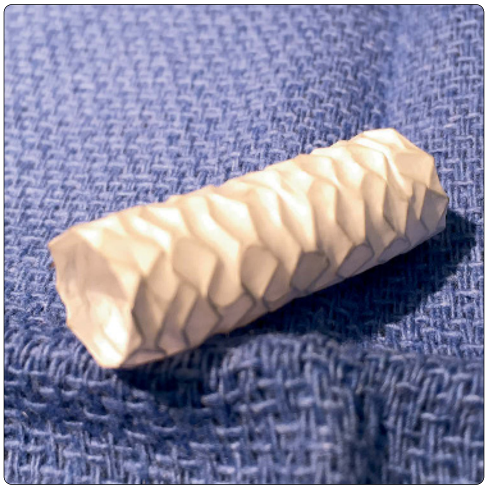


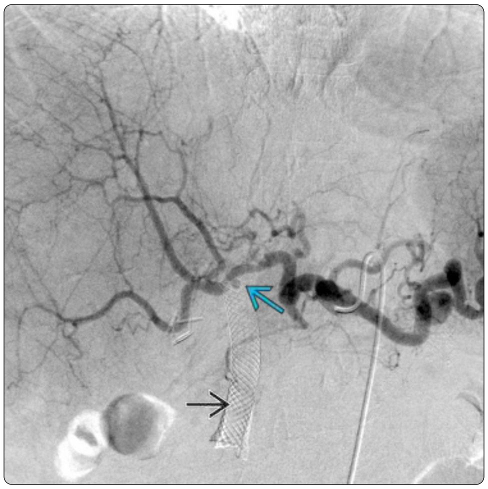
Renal Artery Balloon-Mounted Stent Deployment (Diagnostic Arteriogram)



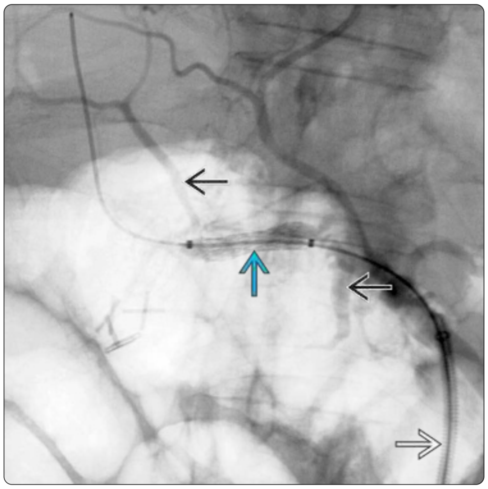
(Left) *A diagnostic right renal arteriogram was obtained via a reverse curve catheter → selectively engaged at the arterial takeoff. High-grade stenosis of the renal artery origin → is apparent.* **(Right)** *Following deployment of a balloon-mounted stent →, but prior to removal of the 0.014" wire ↪, a selective renal arteriogram is obtained by injecting contrast through the guide sheath ⇨. Stenosis of the right renal artery origin is resolved.*

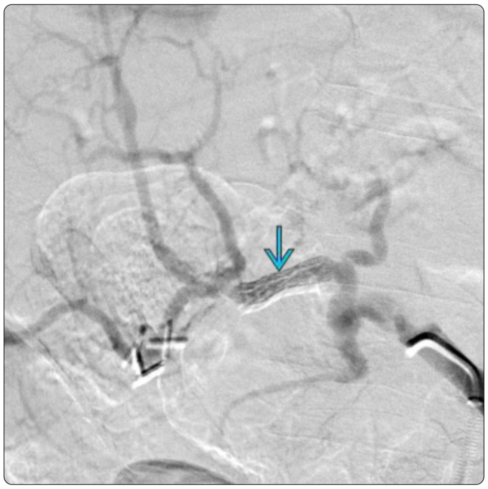
(Left) *The Atrium iCAST is an example of a balloon-mounted, covered stent with PTFE encapsulated stainless steel struts. It's FDA-approved indication is treatment of tracheobronchial strictures, but off-label ability to halt life-threatening arterial bleed exists.* **(Right)** *Immediately following endoscopic placement of a metallic common bile duct stent* ⇨*, massive hematemesis and blood pressure instability occurred. Emergent celiac arteriography revealed a bleeding proper hepatic artery pseudoaneurysm* ⇨*.*


Balloon-Mounted Covered Stent

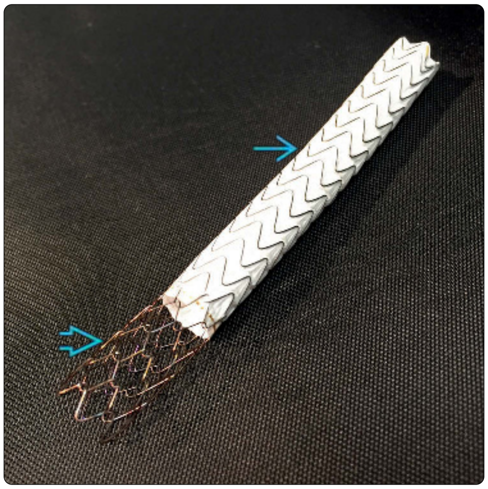

Arteriobiliary Fistula (Emergent Diagnostic Celiac Arteriography)

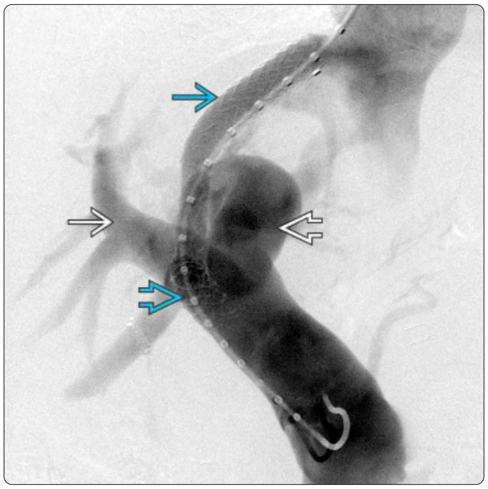
(Left) *Due to the close proximity of the bleed to the adjacent takeoff arteries* ⇨ *and the short available landing zone, we opted to maximize stent position by placing a balloon-mounted stent* ⇨*. A guide sheath* ➡ *was advanced into the celiac artery during stent delivery. As part of a combined procedure, the CBD stent was removed.* **(Right)** *Although some respiratory motion exists, it is evident that the covered stent* ⇨ *has sealed the fistula and excluded the pseudoaneurysm, while maintaining patency of hepatic arteries.*

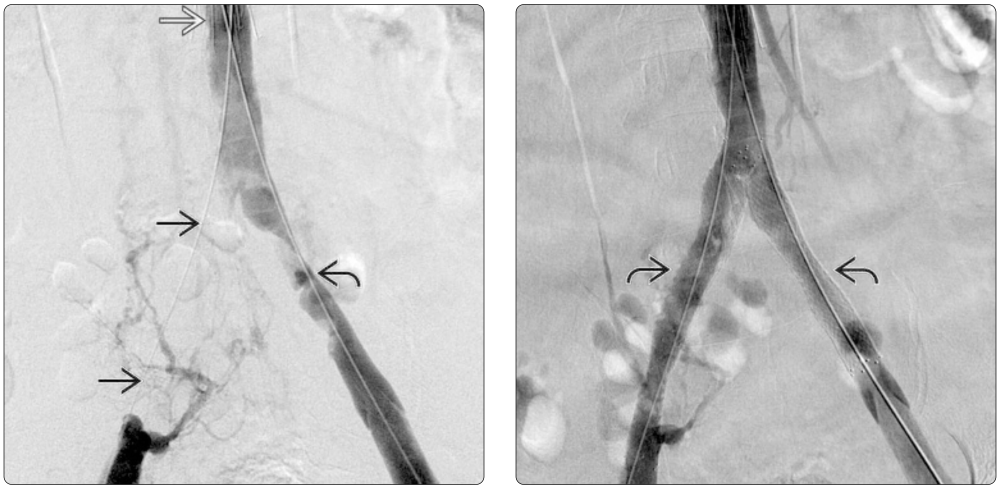

Arteriobiliary Fistula (Placement of Balloon-Mounted Covered Stent)


Arteriobiliary Fistula (Postdeployment Arteriogram)

(Left) *An ePTFE-covered section of stent* ⇨ *is placed within hepatic parenchyma, minimizing tissue ingrowth and permeation of bile, which can reduce stent patency. The bare metal portion of the stent* ⇨ *is placed within the portal vein, allowing antegrade flow to continue unobstructed through the portal vein.* **(Right)** *A portocavogram obtained via flush catheter shows covered* ⇨ *and uncovered* ⇨ *portions of a new TIPS stent, plus antegrade flow within the right* ➡ *and left* ➡ *portal veins.*


TIPS Stent (Gore Viatorr)

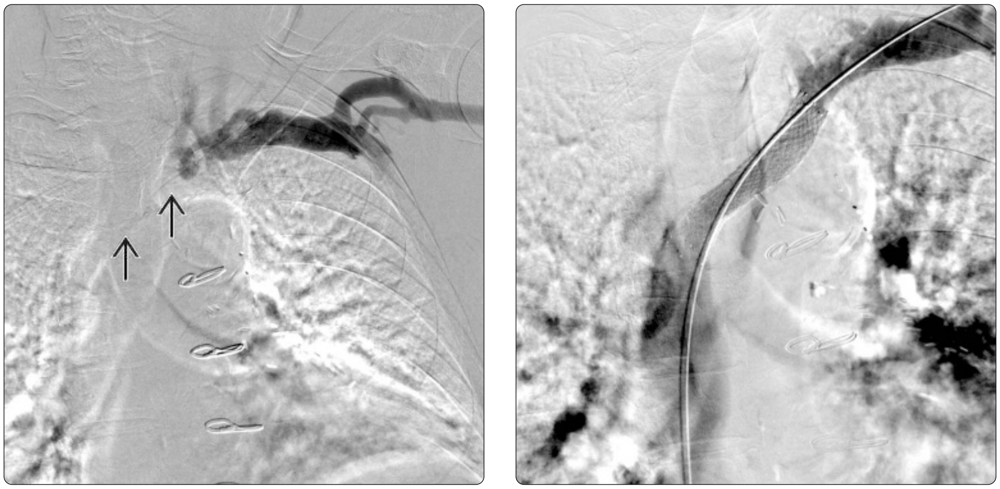

TIPS Stent (Postdeployment Portocavogram)



Pelvic Venous Occlusion (Prestent)

Venous Occlusion (Poststent)

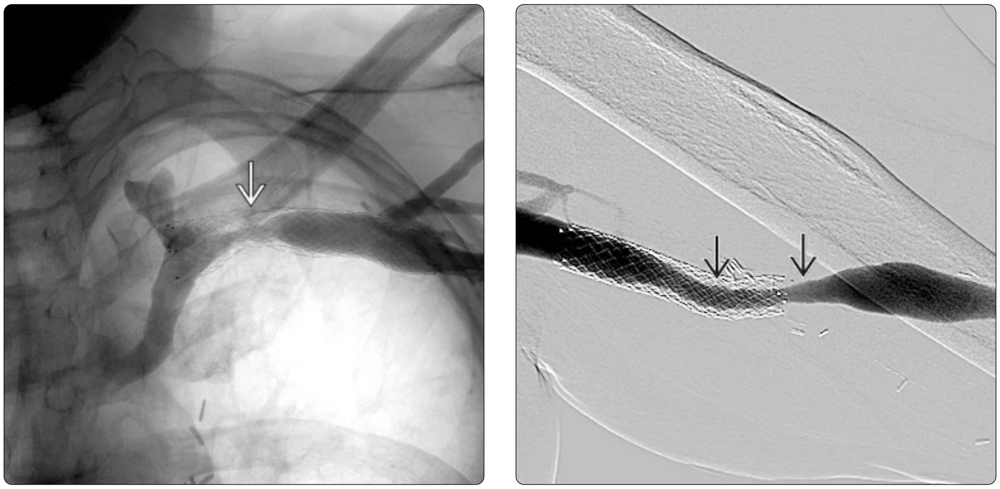
(Left) *With the patient prone on the fluoroscopy table, bilateral contrast injection via popliteal venous sheaths reveals occlusion of the left iliac vein ⇨ and areas of stenosis with the right iliac vein ↪. Note legs of an IVC filter ➡.* **(Right)** *The patient was diagnosed with May-Thurner syndrome. Noncovered, self-expanding stents deployed in the iliac veins ↪, and subsequently angioplastied, restored in-line venous return to the IVC without residual narrowing.*



Central Venous Occlusion (Prestent)

Central Venous Occlusion (Poststent)

(Left) *A patient who had been receiving hemodialysis via a left arm graft complained of recently increased left arm swelling. Venography reveals occlusion of the left brachiocephalic vein ⇨.* **(Right)** *Following wire and catheter recanalization of the occluded vessel, angioplasty was performed. Due to the suboptimal appearance post angioplasty, a stent was deployed. Duration of central venous patency following stent placement vs. angioplasty is mixed in the literature; stent placement is not always beneficial.*



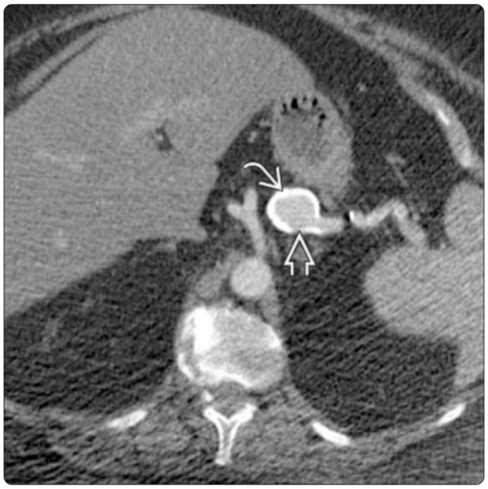
Venous In-Stent Restenosis (Fractured Stent, Subclavian Vein)

Venous In-Stent Restenosis (Hemodialysis Fistula Outflow)

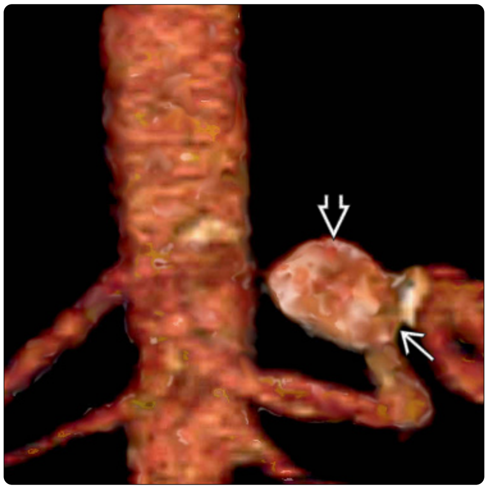
(Left) *Stenting of the subclavian vein often leads to stent fracture and resultant in-stent stenosis. In this case, stenosis was associated with a high-flow hemodialysis fistula and rapidly reoccurred despite repeated angioplasty. A BMS was placed, which fractured ➡ due to repeated extrinsic compression between the clavicle and 1st rib.* **(Right)** *Stenosis and in-stent restenosis ⇨ often occurs within the high-flow venous outflow veins of hemodialysis fistula and grafts.*

(Left) *A large splenic artery aneurysm ➡ with calcified rim ↪ is seen in a young woman who had persistent epigastric tenderness. Splenic artery aneurysms are 4x more common in women than men, particularly if there is a history of multiple pregnancies.* **(Right)** *3D CTA reconstruction again shows the splenic artery aneurysm ➡ and demonstrates a wide neck ➡ to the aneurysm where it arises from the splenic artery. Intervention was felt to be indicated in this patient, as she was symptomatic.*

Stent-Assisted Coil Embolization (Diagnostic CECT)

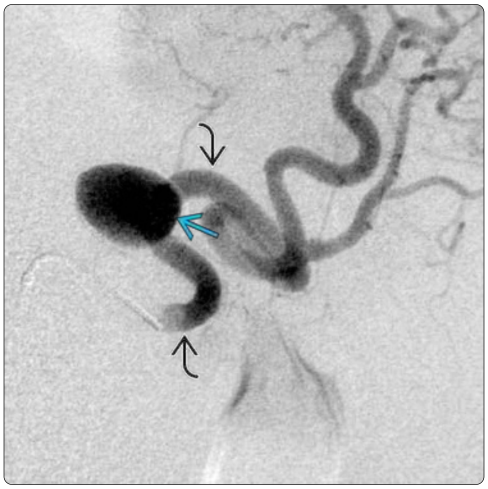


Stent-Assisted Coil Embolization (3D Planning CTA)

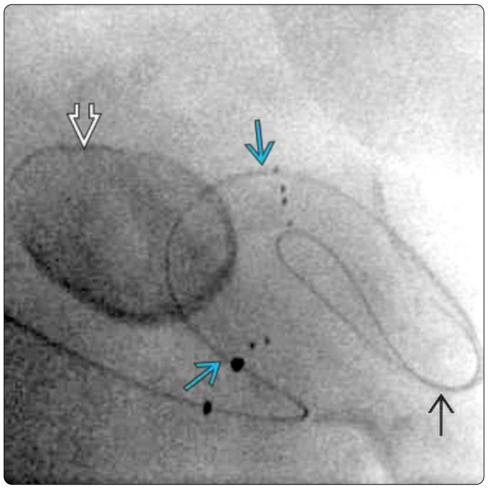


(Left) *DSA splenic arteriography shows a tortuous splenic artery ↪ and confirms the wide aneurysm neck →. Treatment options that were considered included placing a covered stent across the aneurysm neck to exclude the aneurysm vs. coil embolization. The arterial tortuosity precluded the less-flexible covered stent option.* **(Right)** *A noncovered, self-expanding stent → was placed across the neck of the calcified aneurysm ➡. The guidewire → over which the stent was introduced remains in place.*

Stent-Assisted Coil Embolization (Splenic Arteriogram)

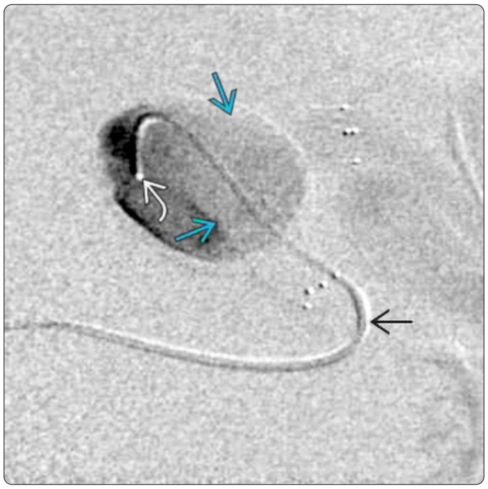


Stent-Assisted Coil Embolization (Bare Metal Stent Placement)

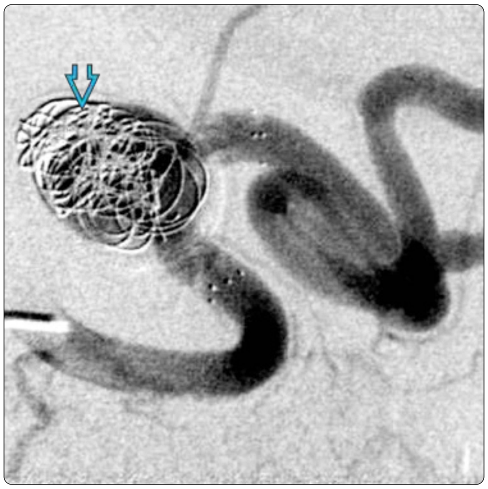


(Left) *DSA shows that a microcatheter → has been negotiated through the interstices of the bare metal stent → so that the catheter tip ↪ is within the aneurysm. Contrast has been injected via the microcatheter, opacifying the aneurysm and confirming the catheter tip position.* **(Right)** *DSA shows multiple embolization coils ⇨ have been introduced into the aneurysm through the microcatheter. The stent prevents the coils from prolapsing into, and occluding, the splenic artery.*

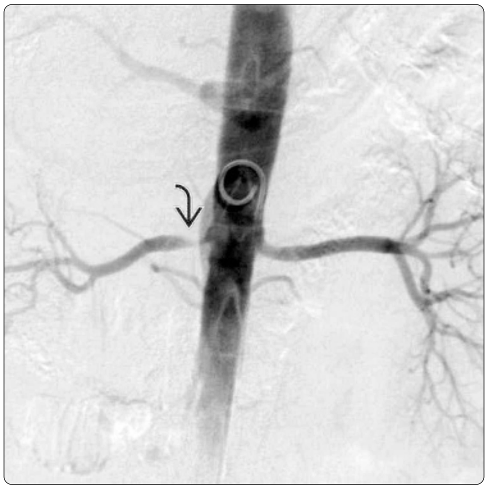
Stent-Assisted Coil Embolization (Microcatheter Through Stent)



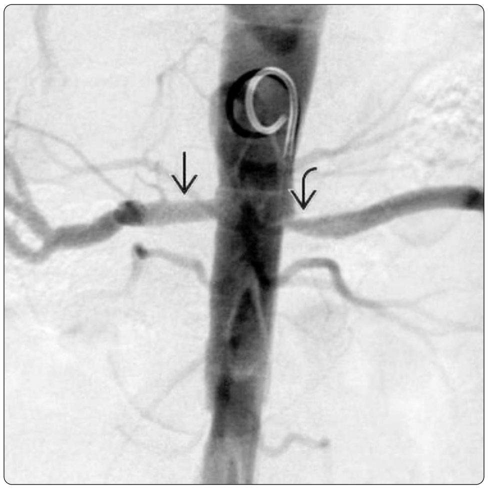
Stent-Assisted Coil Embolization (Coil Deployment into Aneurysm)



In-Stent Intimal Hyperplasia (Diagnostic Aortogram)

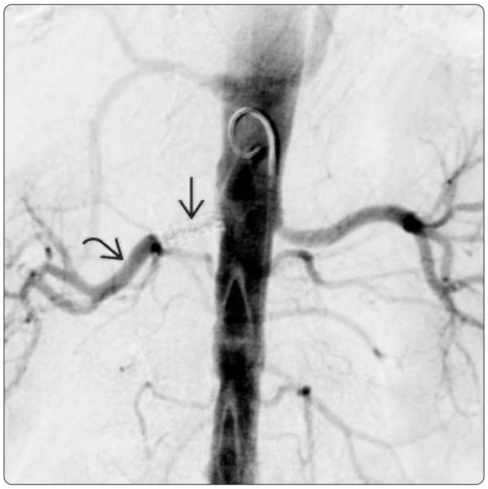


In-Stent Intimal Hyperplasia (Post Deployment of Balloon-Mounted Stent)

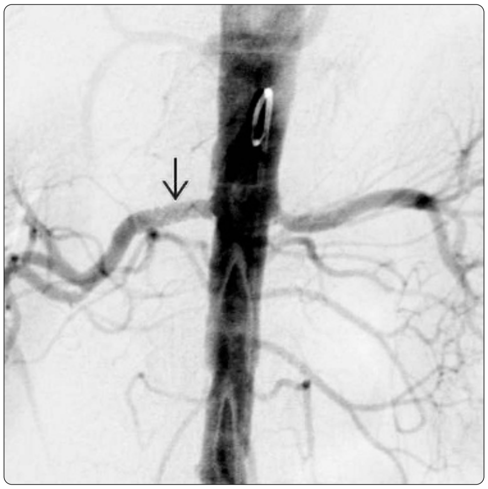


(Left) *High-grade proximal right renal artery stenosis ⤻ is seen in a patient with poorly controlled hypertension and mild renal insufficiency. Endovascular intervention with stent placement was requested.* **(Right)** *There is no evidence of residual stenosis within the proximal right renal artery following placement of a balloon-mounted 5 x 19 mm noncovered stent ➔. Mild left renal artery stenosis ⤻ is also present.*

In-Stent Intimal Hyperplasia (10-Month Follow-Up)

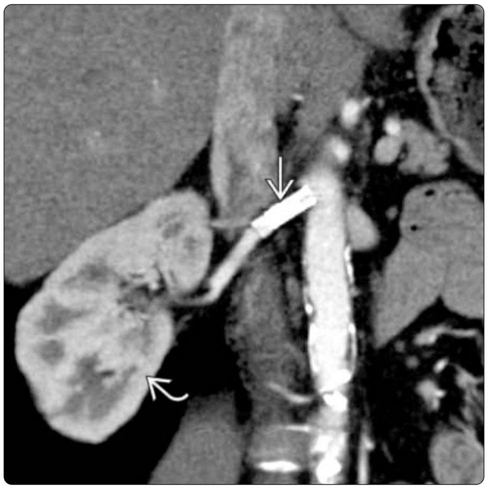


In-Stent Intimal Hyperplasia (Restent)

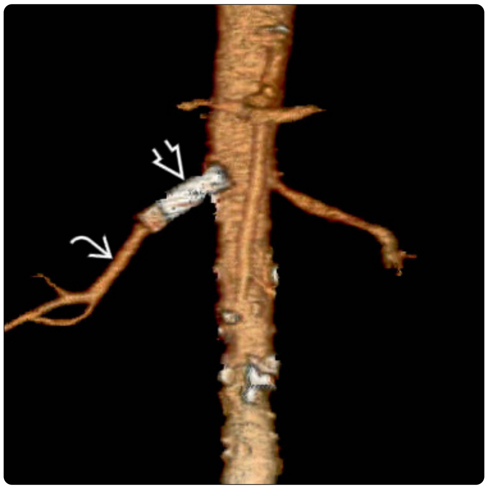


(Left) *Hypertension was initially well controlled after stent placement, but the patient presented 10 months later with recurrent hypertension. Repeat angiography revealed a narrowed lumen ➔ within the stent with a normal-caliber renal artery ⤻ distally, findings consistent with in-stent intimal hyperplasia.* **(Right)** *A new balloon-mounted stent was deployed within the initial stent, correcting the in-stent stenosis and restoring a normal-caliber ➔ right renal arterial lumen.*

In-Stent Intimal Hyperplasia (Follow-Up Imaging)



In-Stent Intimal Hyperplasia (3D CTA)



(Left) *Reformatted arterial phase CECT reveals normal renal perfusion ⤻ and satisfactory stent position ➔, but CT evaluation of the stent lumen is often difficult (or impossible) due to the streak artifact created by the metal density of the stents.* **(Right)** *3D CTA shows the right renal artery stents ⇨ and distal renal artery ⤻, but surveillance of the stent lumen remains difficult due to the artifact produced by the metallic stent. Angiography is often necessary to diagnose intimal hyperplasia when there is clinical concern.*

Stents: Nonvascular

KEY FACTS

TERMINOLOGY

- **Nonvascular stent**: Catheter-delivered artificial conduit; placed in diseased biliary/enteral/urinary/tracheobronchial structures for various indications
    - **Self-expanding**: Spontaneously expand after retraction of delivery system
    - **Balloon-mounted stent**: Externally mounted on angioplasty balloon; balloon inflation deploys stent
    - **Covered stent**: Fabric integrated into inner/outer aspect of metal stent to form impermeable barrier
    - **Plastic ureteral stents**: Designed to treat/prevent upper urinary tract obstruction

PREPROCEDURE

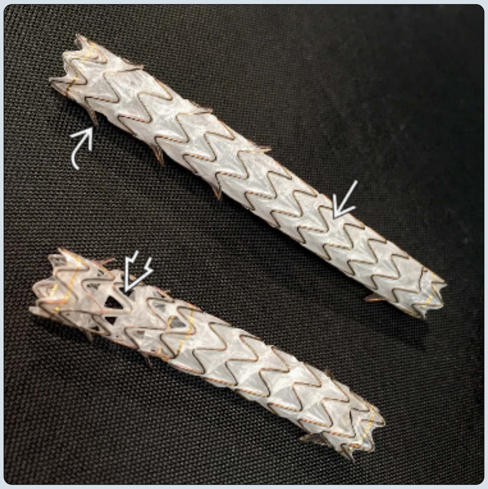
- Indications
    - Recanalization of malignant/some benign obstructions
    - Exclusion of fistula or leak (e.g., urinary, biliary)
- Considerations
    - Goal: Palliation, bridge to surgery, surgical alternative
    - Duration: Permanent vs. temporary
    - Stent characteristics: Covered vs. noncovered, self-expanding vs. balloon expandable

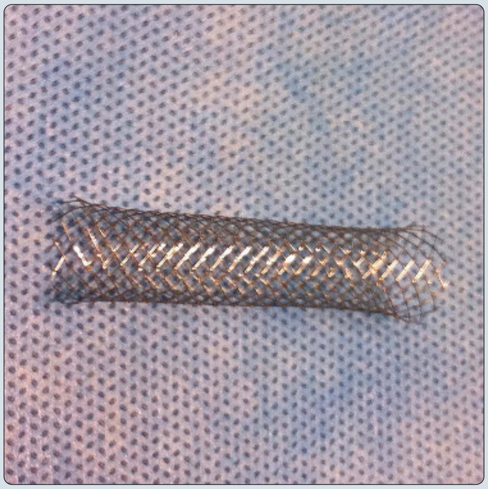
PROCEDURE

- Define length of stenosis, diameter of adjacent nonstenotic duct, and optimal position for stent
- Place stiff guidewire across stenosis
- Retract delivery sheath to deploy stent
- Maintain stent position during deployment
- Pre-/poststent balloon dilatation as necessary

POST PROCEDURE

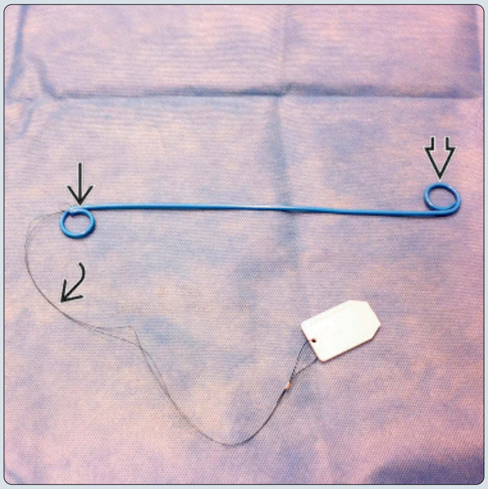
- Follow-up contrast injection if safety catheter left in
    - Biliary and ureteral stents
- 24 hours after GI stenting, assess stent expansion
    - Contrast swallow/upper GI series
    - Plain radiograph


Covered Self-Expanding Biliary Stents


Noncovered Self-Expanding Stent

(Left) *Designed to treat malignant biliary obstruction, the Gore Viabil PTFE cover → halts tumor ingrowth, optional fenestrations ⇨ maintain patency of the cystic duct, and anchoring fins ↪ limit stent migration.* **(Right)** *The Wallstent has high radial force but may foreshorten upon release. It has many applications, including treatment of colonic, biliary, and vascular obstructions. A retrievable version is available to treatment benign biliary obstructions.*

Balloon-Expandable Covered Stent


Plastic Ureteral Stent

(Left) *This Atrium iCAST balloon-expandable, PTFE encapsulated stent is FDA approved for treatment of tracheobronchial strictures. Additional important but off-label uses exist, including emergent treatment of arterial bleeding when exact stent location is necessary (e.g., proper hepatic artery).* **(Right)** *This double J stent is positioned in the ureter with pigtails formed in the bladder → and renal pelvis ⇨. The stent is advanced over a wire. The string ↪ can retract the stent for optimal positioning and is then removed.*

TERMINOLOGY

Definitions

- **Nonvascular stent**: Catheter-mounted artificial conduit; placed in diseased biliary, enteral, tracheobronchial, or urinary structures for various indications
  - Resists luminal narrowing/occlusion caused by extrinsic compression, scarring, malignancy
  - Enhances integrity of luminal wall, promoting closure of fistula/leak
- **Self-expanding stent**: Sheathed in retractable delivery system; spontaneously expands after sheath retraction
  - Used for many nonvascular stent applications
  - Stent is constrained/collapsed on delivery device
    - Radial force anchors stent as it expands
  - Most deploy distally to proximally
  - **Self-expanding metallic stent (SEMS)**: Composed of various materials
    - Elgiloy
      - Cobalt, nickel, and chromium alloy
      - High radial force
    - Nitinol
      - Nickel and titanium alloy
      - Increased flexibility; helpful in angulated regions
      - Lower radial force compared to other stents
    - Stainless steel
    - MR compatibility
      - Most nitinol/Elgiloy stents may be imaged
      - Check manufacturer datasheet
  - **Self-expanding plastic stent (SEPS)**
    - Much less commonly used than SEMS
    - Used in some tracheobronchial and esophageal applications
      - Larger delivery system
      - May be placed at endoscopy/bronchoscopy
    - e.g., Polyflex (Boston Scientific; Natick, MA)
      - Removable covered stent
      - Polyester and silicone construction
- **Balloon-mounted stent**: Externally mounted on angioplasty balloon
  - Balloon inflation required to deploy stent
  - May be used in tracheobronchial applications
- **Covered stent**: Fabric integrated into inner/outer aspect of metal stent to form impermeable barrier
  - Most common fabrics: Silicone, polyurethane, expanded polytetrafluoroethylene
  - More resistant to tumor ingrowth than noncovered
  - Reduces epithelialization of metal lattice
    - Higher risk of stent migration
  - Partially or fully covered
    - Uncovered proximal and distal ends
      - Increases epithelial ingrowth
      - Reduces risk of stent migration
    - Removal of fully covered stents may be possible
      - WallFlex, esophageal stent (Boston Scientific; Natick, MA)
- **Location-specific stents**
  - **Plastic upper urinary tract stents**: Nephroureteral, ureteral
    - Ureteral obstruction
    - Ureteral leak, allowing injured ureter to heal over stent "scaffolding"
  - **Biliary**
    - Biliary obstruction: Consider obstructive etiology and patient's life expectancy in stent choice
      - Life expectancy < 1 year: Permanent stent
      - Benign etiology: Retrievable stent (e.g., plastic, covered)
    - Biliary leak: Retrievable stent (typically plastic)
      - Plastic biliary stents placed via endoscopy

PREPROCEDURE

Indications

- Recanalization (palliative, bridge to surgery)
  - Malignant obstruction of
    - Biliary tree
    - Esophagus, stomach, duodenum, colon
    - Ureter/bladder
    - Tracheobronchial tree
  - Benign esophageal or colonic stricture
    - Temporizing measure
- Exclusion (palliative, surgical alternative)
  - Fistula or perforation (covered stent)
  - Urine leak (ureteral stent)

Getting Started

- Things to check
  - Clinical history and physical examination
    - Elucidate benign vs. malignant etiology
- Medications
  - Antibiotic prophylaxis (various options)
    - Biliary and ureteral stenting
- Equipment list
  - Guidewires and catheters
    - 5-Fr directional catheter (e.g., Kumpe)
    - Hydrophilic angled-tip/straight guidewire to cross obstruction
    - 0.035" stiff guidewire (e.g., Amplatz) to deploy stent
  - Balloon dilatation: Consider dilatation if unable to cross tight stenosis with SEMS delivery system
    - Size depends on site, length, and severity of stenosis
    - Often not necessary to predilate stenosis
    - Beware of possibility of perforation
    - Consider dilatation if unable to cross tight stenosis with SEMS delivery system
    - Not necessary to dilate after deployment, but consider if poor stent expansion
  - Ureteral stenting
    - Double J ureteral stent set
      - 8- to 10-Fr: 20-28 cm in length

Stent Considerations

- Covered vs. noncovered
  - Covered stents reduce malignant tumor ingrowth
- Permanent vs. retrievable
- Deployment mechanism (self- vs. balloon expandable)
  - Balloon-mounted stents can be placed more exactly, with greater force, but may have difficulty navigating angles along delivery path
- Stent properties

  - Shortening ratio: Stents differ in degree of shortening as they expand (proprietary designs)
  - Radial force: High radial force may cause pain (e.g., esophagus, biliary)
  - Flexibility: New stent designs have increased flexibility
    - Helpful in angulated structures
  - Antimigration mechanisms: Stent design features that reduce risk of stent migration
    - Flared or looped ends, external fins
  - Metallic stents
    - Most metallic stents are not retrievable, carefully consider their use in benign disease
    - Metal stent placement may affect future treatment options (e.g., surgery)
    - Long-term use associated with late complications
  - Plastic stents
    - Improves ease of advancement of stent
    - Improved inner:outer diameter ratio (large lumen)
    - e.g., Ultrathane (Cook Medical; Bloomington, IN), Percuflex (Boston Scientific; Natick, MA)
- Appropriate multidisciplinary management plan
  - Consensus as to stent type/necessity

PROCEDURE

Procedure Steps

- **General**
  - Define length of stenosis, diameter of adjacent nonstenotic duct, and optimal position for stent
  - Cross stenotic lesion
    - Gently advance floppy-tip guidewire across stenosis
      - ☐ Hydrophilic angle-tip/straight guidewire useful
    - Deploy stent over stiff 0.035" guidewire
- **SEMS deployment**
  - Retract delivery sheath to deploy stent
  - Monitor deployment with fluoroscopy
  - Maintain stent position during deployment
    - Stent position may change during deployment
    - SEMS may be reconstrained/recaptured
      - ☐ Radiopaque marker delineates reconstrainment limits of stent delivery system
      - ☐ Stent deployed beyond this marker ("point of no return") can not be reconstrained
  - Postdeployment balloon dilatation often unnecessary
    - May take 1-2 days for complete expansion
- **Biliary stenting**
  - Covered vs. noncovered stent use controversial
    - Covered stents theoretically associated with less tumor ingrowth/occlusion
    - Covered stents may have higher incidence of cholecystitis and pancreatitis
  - Select stent length that extends at least 1-2 cm proximal and distal to stenosis
- **Gastrointestinal stenting**
  - Esophagus
    - Covered stents are SEMS of choice for stricture
    - New covered SEMS designs reduce migration risk
      - ☐ Ultraflex/WallFlex esophageal stents (Boston Scientific; Natick, MA)
    - Covered stents utilized for fistula treatment
  - Duodenum
    - Noncovered self-expanding stent
      - ☐ Wallflex Duodenal (Boston Scientific; Natick, MA)
    - Simultaneous biliary stent if obstruction present
  - Colon
    - Noncovered stent typically used in United States
      - ☐ Wallstent
      - ☐ Wallflex Colonic (Boston Scientific; Natick, MA)
- **Ureteral stenting**
  - Indwelling percutaneous nephrostomy in place
    - Perform antegrade nephrostogram to confirm position and assess ureteral patency
  - Negotiate across stenosis using catheter and guidewire
  - Estimate optimal length for double J ureteral stent
  - Deploy stent after introducing over guidewire

POST PROCEDURE

Postprocedure Imaging

- Follow-up contrast injection if safety catheter left in
  - Biliary and ureteral stents
- 24 hours after GI stenting, assess stent expansion
  - Water contrast swallow/upper GI series
  - Plain radiograph

OUTCOMES

Complications

- Immediate/periprocedural complication(s)
  - Hemorrhage: Latrogenic vascular injury during procedure
  - Pain: Stent placement, position, over dilation
  - Stent damage/fracture
- Delayed complication(s)
  - Stent obstruction
    - Tumor ingrowth: Most common complication, dependent on tumor and stent type
      - ☐ May require new indwelling, overlapping stent
    - Food impaction
      - ☐ May require endoscopic removal
  - Stent migration: Incidence ↑ for covered vs. noncovered
    - Consider new overlapping stent
  - Perforation from stent erosion
    - ↑ incidence for patients receiving bevacizumab
- Overall
  - Complicating risk factors include stent type, operator experience, stricture location, concommitant use of chemotherapy, radiation, and Avastin

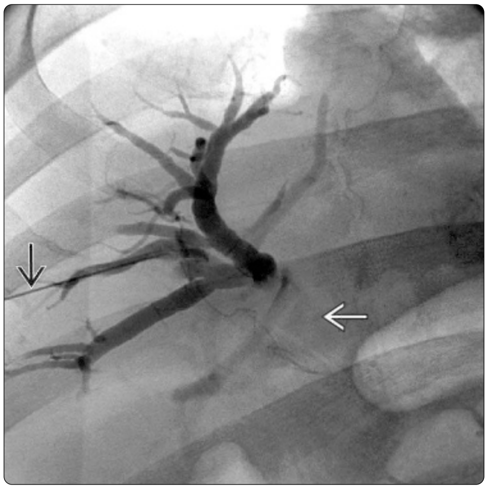
Expected Outcomes

- In patients with reasonable prognosis, stents can improve survival and quality of life
- High technical stent placement success
- High early clinical success; stents occlude over time
  - Tumor ingrowth (malignancy)
  - Stent encrustation/inspissation

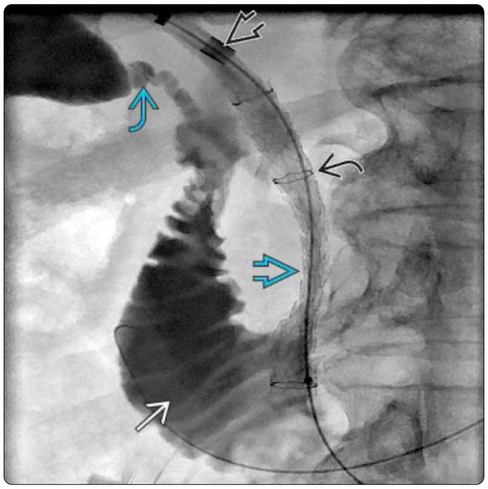
SELECTED REFERENCES

1. Nam HS et al: Current status of biliary metal stents. Clin Endosc. 49(2):124-30, 2016

Biliary Stent (Prestent Percutaneous Cholangiogram)

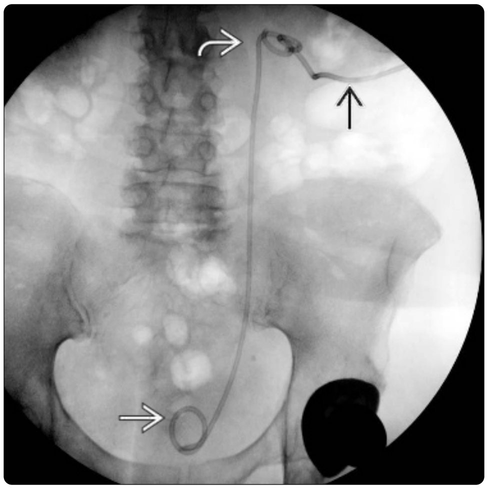


Biliary Stent (Poststent Cholangiogram)

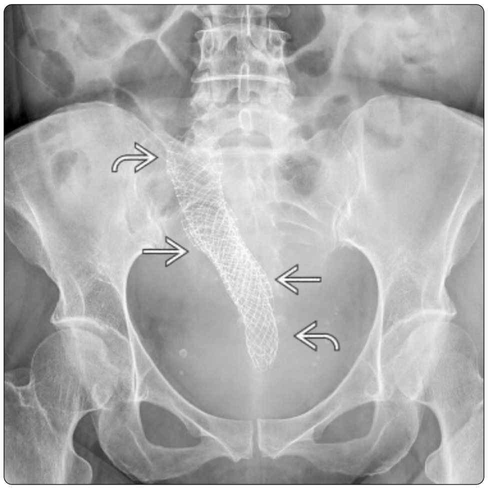


(Left) *Contrast injection via a 21-gauge Chiba needle → reveals dilated right hepatic bile ducts and CBD obstruction ➡ in this patient with a pancreatic head malignancy.* **(Right)** *Contrast injection via a delivery sheath ⇨ confirms CBD patency with contrast spilling into duodenum ➡ following placement of a self-expanding biliary stent. The stent contains covered (above) and fenestrated (below) segments separated by a radiopaque band ↪. Cholangioplasty may decrease residual CBD stenosis ⇨. Note the patent cystic duct ↪.*

Ureteral Stent

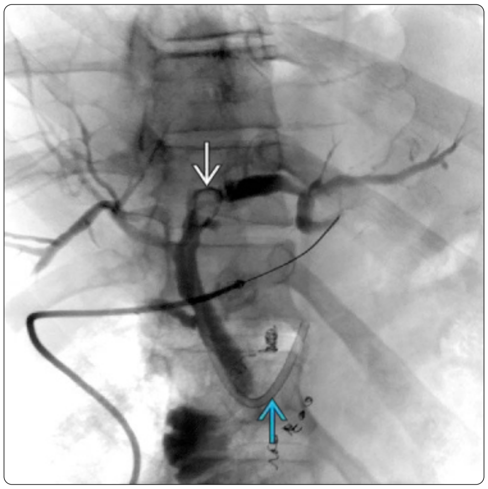


Colorectal Stent

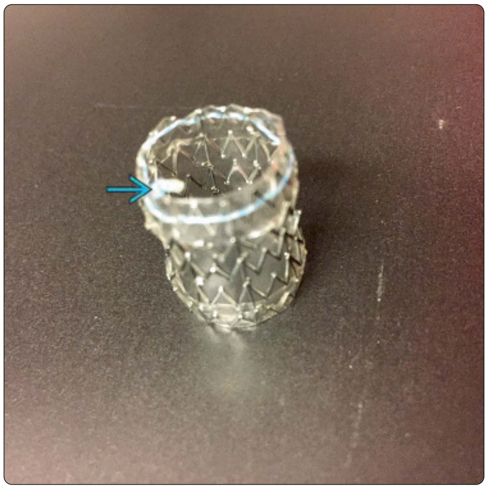


(Left) *A double J ureteral stent has been deployed in a patient with ureteral obstruction from peritoneal carcinomatosis. The proximal pigtail ↪ is in the renal pelvis, and the distal pigtail ➡ in the bladder. A safety nephrostomy catheter → has been temporarily left indwelling.* **(Right)** *An abdominal radiograph was obtained in a 47-year-old woman with metastatic gastric cancer, which was extrinsically compressing and obstructing the colon. One colorectal stent ↪ extends through and overlaps with a 2nd stent ➡.*

Plastic Temporary Biliary Stent



Tracheobronchial Stent



(Left) *Shown is an example of a plastic CBD stent → placed during upper endoscopy in a patient with elevated bilirubin. Subsequently, this cholangiogram revealed an obstructing stone ➡ in the left main biliary duct. The stone and temporary stent were subsequently removed with a snare.* **(Right)** *This example of a tracheobronchial covered stent may be placed during bronchoscopy. This particular stent may be manipulated after deployment by grasping and pulling on the blue radiopaque band →.*

Embolic Protection

KEY FACTS

TERMINOLOGY

- **Embolic protection device (EPD)**: Intravascular device designed to prevent dislodged plaque/debris/embolic material from occluding distal vasculature
- Various designs
    - **Filter**: Guidewire-mounted porous filtering device; deployed distal to target lesion
    - **Distal occlusion**: Balloon occlusion beyond lesion
    - **Proximal flow blockage**: Proximal CCA balloon occlusion with 2nd occlusion balloon in ECA; aspiration creates flow reversal/prevents emboli

PREPROCEDURE

- Indication: Particles/debris from plaque/cholesterol/thrombus may embolize during revascularization
    - EPD significantly decreases embolic complications
- Contraindications for EPD use
    - Inadequate "landing zone" for EPD
    - Chronic total occlusion revascularization

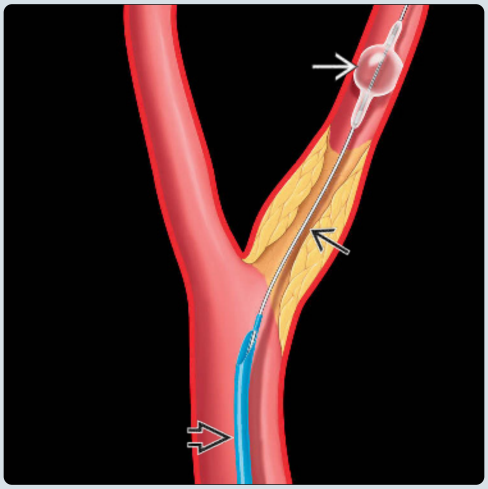
PROCEDURE

- Selectively catheterize artery containing lesion
    - Obtain DSA of lesion & EPD "landing zone"
- Exchange selective catheter for EPD delivery sheath
    - Position sheath proximal to lesion
- Introduce/deploy EPD using fluoroscopic guidance
    - Confirm satisfactory position with DSA
- Perform intervention; recapture/retrieve EPD

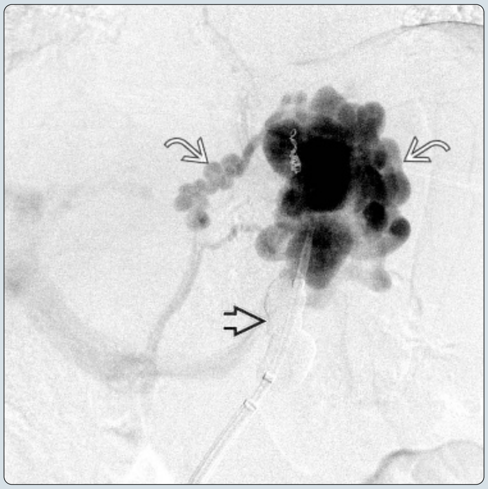
OUTCOMES

- **Most feared complication**
    - Distal embolization due to EPD failure/malpositioning
        - Periprocedural stroke associated with CAS
        - Distal limb ischemia during PAD intervention
- **Expected outcome**
    - Prevention of embolic complications from catheter-based intervention, such as PTA, atherectomy, & stenting

Distal Occlusion Embolic Protection: Guidewire-Mounted Balloon Device

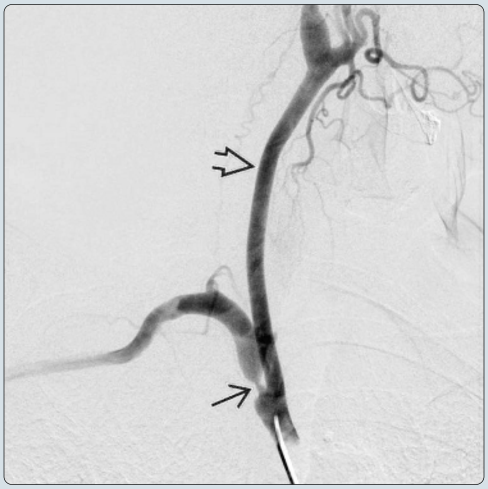


Distal Occlusion Balloon Device Used During Sclerosis of Gastric Varices

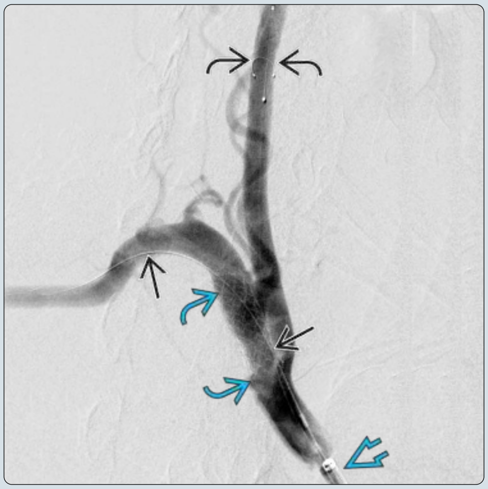


(Left) *Graphic of a distal occlusion embolic protection device (EPD) shows a guidewire-mounted balloon ➡ that is introduced via a sheath ⇨, inflated in the ICA beyond the stenosis →. A stent can be introduced over the guidewire and any debris aspirated via the sheath.* **(Right)** *Distal balloon occlusion is rarely used now in carotid interventions. It is more commonly used with various venous procedures such as ablation of gastric varices ↪ (BRTO), in which a balloon ⇨ is inflated during variceal sclerosis.*

Distal Filter EPD: Right Subclavian Artery Stenting



Distal Filter EPD: Right Subclavian Artery Stenting



(Left) *Brachiocephalic DSA obtained in a patient with right upper extremity claudication demonstrates a severe stenosis → of the proximal right subclavian artery. The right common carotid artery (CCA) ⇨ is widely patent.* **(Right)** *A 6-Fr vascular sheath ⇨ was placed in the brachiocephalic artery, and a distal filter EPD ↪ was deployed in the CCA below the carotid bifurcation so as to protect the intracranial vessels during intervention. A guidewire → was advanced across the subclavian stenosis, and a stent ↪ was placed.*

Embolic Protection

TERMINOLOGY

Synonyms

- Cerebral protection device

Definitions

- **Embolic protection device (EPD)**: Intravascular device designed to prevent dislodged plaque/debris/embolic material from occluding distal vasculature
  - Used with interventions in various vascular beds
    - Internal carotid artery (ICA)/vertebral arteries
    - Coronary arteries/saphenous vein grafts
    - Renal arteries
    - Upper/lower extremity arteries
    - Venous interventions
  - 3 categories based on mechanism of action
    - **Filter**: Guidewire-mounted porous filtering device; deployed distal to target lesion
      - Variable filter diameters permit optimal vessel apposition for capturing embolic debris
      - Filter collapsed within delivery sheath while crossing target lesion
      - Sheath retraction deploys filter within vessel
      - After filter deployment, guidewire on which filter mounted becomes working guidewire
    - **Distal occlusion**: Balloon occlusion, positioned distal to lesion
      - Early form of embolic protection; now infrequently used for ICA interventions
      - Balloon occlusion catheters still used for embolic protection in other vascular beds
      - May be used with liquid embolic agents to prevent nontarget embolization
    - **Proximal flow blockage**: Proximal occlusion of target artery using catheter-compatible sheath, with occlusion balloon at distal end (a.k.a. circulatory control device)
      - Balloon inflated in common carotid artery (CCA) proximal to lesion
      - Additional smaller occlusion balloon placed via sheath into external carotid artery (ECA)
      - Can actively aspirate sheath; create flow reversal to prevent ICA emboli
      - 1 proprietary design permits active flow reversal; central lumen of sheath connected via external filter into common femoral vein; creates temporary arteriovenous fistula
      - Central lumen of sheath also permits guidewire/catheter/stent introduction

PREPROCEDURE

Indications

- **General**
  - Particles/debris from plaque/cholesterol/calcium/thrombus may embolize during revascularization interventions (e.g., angioplasty, atherectomy, stents)
    - Embolic events related to
      - Guidewire passage through target lesion
      - Passage of any device through target lesion
      - Angioplasty (PTA) dilatation of target lesion
      - Failure of atherectomy device to completely capture all excised atheroma
      - Stent placement at target lesion
      - Postdilatation of stent after deployment
- **Carotid artery stent (CAS) placement**
  - FDA mandated use of EPD during CAS procedures
    - Significant periprocedural stroke rate reduction
- **Renal artery stent (RAS) & angioplasty procedures**
  - Many investigators recommend EPD use if possible
    - Cholesterol emboli potential etiology of postprocedure decline in electrolytes, glomerular filtration rate (eGFR)
  - Short renal artery length may preclude use
- **Peripheral artery disease (PAD) interventions**
  - Some recommend use during revascularization interventions (especially atherectomy, thrombolysis)
    - Decreased likelihood of distal limb (e.g., calf/foot) ischemia from embolic debris
  - Impractical with infrapopliteal interventions
    - Very small-caliber target arteries
- **Transcatheter aortic valve replacement (TAVR)**
  - Neurologic complications after TAVR may be reduced with cerebral EPD use
    - Clinically "silent" brain infarctions seen on MR are associated with neurocognitive function changes
      - These infarctions occur in as many of 80% of patients after TAVR
    - Recent multicenter randomized controlled trial compared TAVR with and without EPD use
      - EPD consists of 2 filters positioned in brachiocephalic and left CCA before TAVR
      - Device captured significant debris in 99% of patients randomized to EPD use
      - Strokes at 30 days were 9.1% (control group) and 5.6% (patients with EPD); not statistically significant ($p = 0.25$)
      - 42% reduction in new lesion volume in protected territories seen on MR
    - Metaanalysis of randomized controlled trials of EPD use during TAVR
      - EPD use associated with reduced imaging markers of cerebral infarction
      - Trend toward lower risk for neurologic deterioration scores at discharge
- **Liquid embolization & sclerosant interventions**
  - Balloon inflated proximal or distal to embolization target when using liquid embolic agent
    - Temporarily stops/slows blood inflow/outflow
    - Prevents liquid embolic entry into circulation
    - Slow balloon deflation after embolization allows gradual resumption of blood flow
      - Minimizes circulating bolus of embolic liquid
  - Most frequently used with venous procedures
    - e.g., balloon-occluded retrograde transvenous variceal obliteration, vascular malformations

Contraindications

- Chronic total occlusion revascularization
  - Cannot initially use filter/distal occlusion device
    - Can only pass/deploy device via patent lumen
  - If lumen reestablished, then may use distal device

- Inadequate "landing zone" for EPD
  - Excessively small vessel diameter distal to lesion
    - Vessel caliber may not accommodate size of EPD
  - Insufficient distance between target lesion and "landing zone" for EPD deployment
    - e.g., short arterial length before bifurcation point
      - Problematic with filter/distal EPD
      - Common with renal/popliteal arteries
    - Very proximal lesion (e.g., great vessel origins)
      - May preclude proximal flow blockade device

Preprocedure Imaging

- **US**
  - Displays/characterizes target lesion/stenosis
    - Severity/length of lesion/stenosis; vessel caliber
  - Displays adjacent normal vessel segments
    - May not adequately show EPD "landing zone"
  - Most useful in evaluating carotid lesions
    - May evaluate/characterize renal lesions
    - Usually inadequate for characterizing PAD lesion
    - Can characterize carotid plaque
      - Assessment of plaque stability/instability
      - May be predictive of embolization risk
  - Usually need supplemental CTA/MRA
- **CTA**
  - Requires contrast administration to opacify vessels
    - Excellent anatomic detail with CTA
      - Displays/characterizes target lesion/stenosis
      - Can obtain accurate vessel measurements; use to determine appropriate EPD size/design
      - Can display/characterize EPD "landing zone"
  - Can obtain 3D, volume-rendered MIP images
    - Excellent for procedure planning
      - Displays vessel tortuosity, bifurcations
      - Characterizes runoff vasculature distal to lesion
- **MR**
  - May obtain similar anatomic detail as with CTA
  - May have inaccurate vessel measurements
    - Overestimation of stenosis
    - Difficult to determine appropriate EPD size/design
    - May poorly depict distal stenoses
  - May use to characterize carotid plaque
- **DSA**
  - "Gold standard" in assessing vasculature
    - Typically combined with intervention
  - Displays lumen characteristics only
    - Poor evaluation of plaque characteristics
    - Unsubtracted images can display significant Ca++
  - Can obtain accurate vessel measurements
    - Use to determine appropriate EPD size/design
    - Use to determine appropriate device size
      - e.g., angioplasty balloon, stent
  - Excellent for procedure planning/guidance
    - Shows real-time flow characteristics
      - Can accurately assess flow reversal adequacy

Getting Started

- Things to check
  - Clinical history and physical examination
    - Indications for procedure
    - Indications for embolic protection use
  - Review pertinent preprocedural imaging
    - Appropriate anatomy for embolic protection
    - Sizing/type of EPD
  - Allergies
  - Laboratory parameters
    - eGFR
      - Normal creatinine and eGFR > 60
    - CBC
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ration (INR) ≤ 1.5
      - Normal prothrombin time, partial thromboplastin time
  - Written informed procedural consent obtained
- Medications
  - Sedation/analgesia medications
  - Anticoagulant
    - Heparin 2,000-5,000 units IV
- Equipment list
  - **Filter EPD**
    - RX Accunet (Abbott Vascular; Santa Rosa, CA)
    - AngioGuard XP (Cordis; Warren, NJ)
    - FilterWire EZ (Boston Scientific; Natick, MA)
    - FiberNet (Lumen Biomedical; Plymouth, MN)
    - Emboshield NAV^6 (Abbott)
    - Spider (ev3; Plymouth, MN)
  - **Distal occlusion EPDs**
    - Guidewire-mounted occlusion balloon
      - GuardWire temporary occlusion system (Medtronic; Minneapolis, MN)
    - Large-diameter occlusion balloons; catheter-mounted, designed for over-the-wire placement (rarely used for distal embolic protection)
      - Coda balloon catheter (Cook Medical; Bloomington, IN)
      - Reliant Balloon Catheter (Medtronic Endovascular; Santa Rosa, CA)
  - **Proximal flow blockage EPDs**
    - Gore flow reversal (WL Gore; Newark, DE)
    - Mo.MA device (Invatec; Brescia, Italy)

PROCEDURE

Procedure Steps

- **General**
  - Selectively catheterize artery containing lesion
    - Position catheter proximal to lesion
  - Obtain DSA of lesion/EPD "landing zone"
    - For CAS, mandatory to obtain intracranial DSA before EPD deployment or any intervention
  - Exchange selective catheter for EPD delivery sheath
    - Position sheath proximal to lesion
  - Administer heparin prior to EPD deployment
  - Introduce/deploy EPD using fluoroscopic guidance
    - Confirm satisfactory position with DSA
    - Monitor EPD position during procedure
      - Avoid excessive manipulation or repositioning of EPD; may lead to vasospasm, dissection
  - Perform intervention

    - Obtain DSA prior to EPD removal
      - Assess for any vasospasm/other abnormality
  - Recapture/retrieve EPD
  - Obtain completion DSA images
- **Distal filter/distal occlusion device**
  - Carefully cross lesion with collapsed EPD
    - May use roadmap guidance while crossing lesion
  - Obtain DSA via sheath prior to EPD deployment
    - Confirm satisfactory EPD position
      - EPD must be sufficiently distal to lesion to permit PTA/stenting without contacting EPD
  - Deploy EPD using fluoroscopic guidance
- **Proximal flow blockage device**
  - Advance balloon-tipped sheath over guidewire
  - Position balloon in CCA; confirm position with DSA
    - Balloon must be sufficiently proximal to lesion to permit intervention without contacting EPD
  - Introduce balloon wire via balloon sheath ECA port
    - Position balloon wire in ECA; confirm with DSA
  - Perform DSA before inflating either balloon
  - 1st inflate ECA balloon then CCA balloon
    - Inflate balloons using dilute contrast
  - Monitor patient response to balloon occlusion
    - Check patient mental/motor status
    - Deflate balloons if intolerance
  - If using active flow reversal, external filter connected to sheath sideport and to previously placed femoral vein sheath; this causes flow reversal
    - May also actively aspirate sheath
  - Confirm flow reversal with DSA before intervention

Alternative Procedures/Therapies

- Cervical transcarotid arterial access of CCA
  - Direct access of CCA with placement of proximal blood flow reversal EPD followed by angioplasty and CAS
    - Completely avoids negotiating tortuous and atherosclerotic thoracic aortic arch
    - May reduce incidence of distal cerebral embolization during CAS procedure
  - Up to 8% of embolic strokes associated with CAS occur on contralateral side of intervention
    - Suggests that embolization occurs during manipulation of guidewires and catheters within aortic arch, not only during stent placement

OUTCOMES

Complications

- Most feared complication(s)
  - Failure to prevent distal embolization causing
    - Periprocedural stroke associated with CAS
    - Distal limb ischemia during PAD intervention
    - Declining renal function associated with RAS
  - Various causes of EPD failure
    - Inappropriately sized/malpositioned EPD
    - Embolic burden exceeds capacity of EPD
    - Incomplete recapture of filter-type EPD
    - Inadequate aspiration/flow reversal of proximal flow blockage EPD
- Immediate/periprocedural complication(s)
  - Inability to retrieve/recapture EPD
  - Local vasospasm associated with EPD
    - Occurs with excessive manipulation of EPD
    - May be severe; untreated could cause ischemia/stroke
    - Treat with 100 μg intraarterial nitroglycerin
      - May administer additional doses as needed
  - Intraprocedural arterial thrombosis
    - May be secondary to poor/sluggish intraarterial flow, inadequate anticoagulation

Expected Outcomes

- Prevention of embolic complications from catheter-based interventions, such as PTA, atherectomy, & stenting
  - Single-center series and metaanalyses show lower incidence of procedural complications when EPDs used

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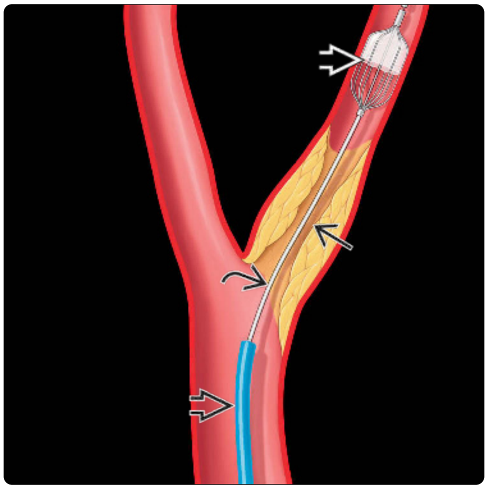
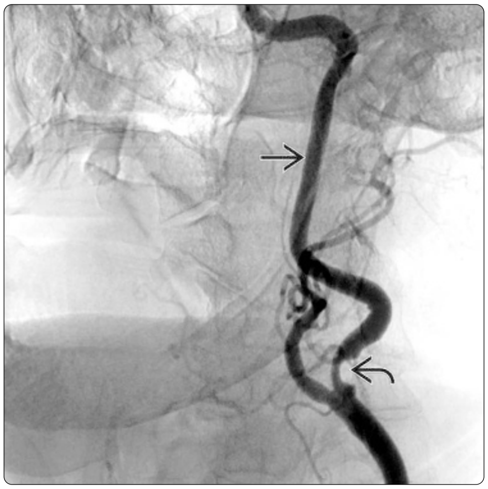
(Left) *Graphic shows a distal filter EPD ⇨ that has been deployed beyond an atherosclerotic ICA stenosis →. The filter is mounted on a guidewire ↪ and is introduced via a guiding sheath ⇨ that is positioned in the CCA. The guidewire will be used for subsequent stent placement.* **(Right)** *Left common carotid DSA shows a severe stenosis ↪ of the proximal ICA. Distal to the stenosis, the ICA resumes a normal caliber →. Based on imaging, an appropriately sized EPD is chosen.*

Distal Filter EPD: Graphic of Deployed Filter EPD

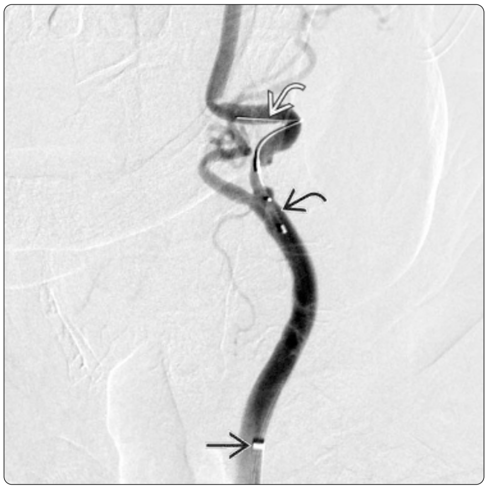


Distal Filter EPD: Initial Common Carotid DSA Imaging

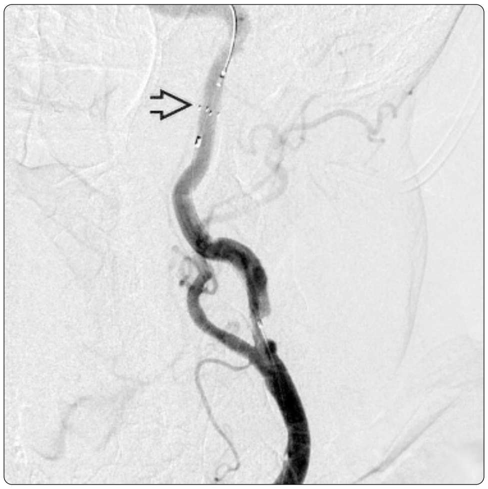


(Left) *DSA shows that a sheath → has been placed in the CCA, and the distal filter EPD ↪ has been introduced. The guidewire ↪ at the tip of the EPD has been successfully advanced through the ICA stenosis.* **(Right)** *After the EPD has been advanced across the ICA stenosis, the sheath constraining the device is withdrawn, and the self-expanding EPD ⇨ is deployed. There must be sufficient distance between the device and the stenosis for stent placement without contacting the EPD with the stent delivery system.*

Distal Filter EPD: Crossing Stenosis With EPD

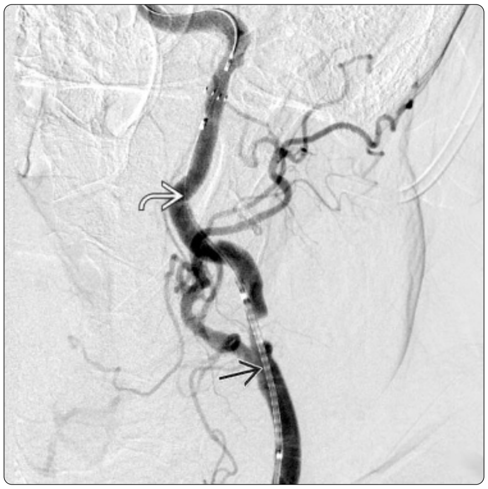


Distal Filter EPD: EPD Deployed Distal to Stenosis

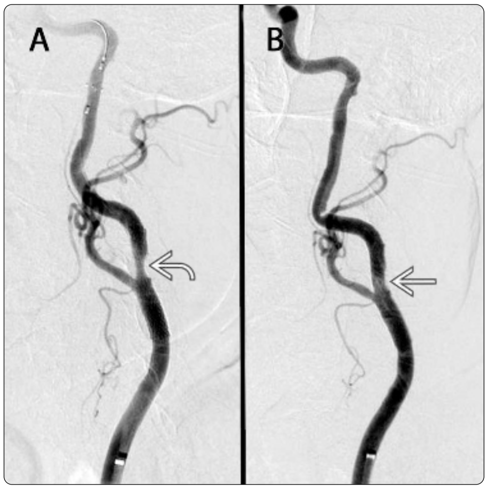


(Left) *DSA shows that a carotid stent → has been introduced via the sheath over the guidewire ↪ of the EPD. The stent will be positioned bridging the stenosis. Contrast injection via the sheath is used to confirm an appropriate stent position prior to deployment.* **(Right)** *DSA images obtained after deployment of the stent show (A) a satisfactory position to the stent with a minimal residual stenosis ↪. (B) After PTA of the stent to eliminate the residual stenosis →, the EPD is retrieved, and a completion DSA is obtained.*

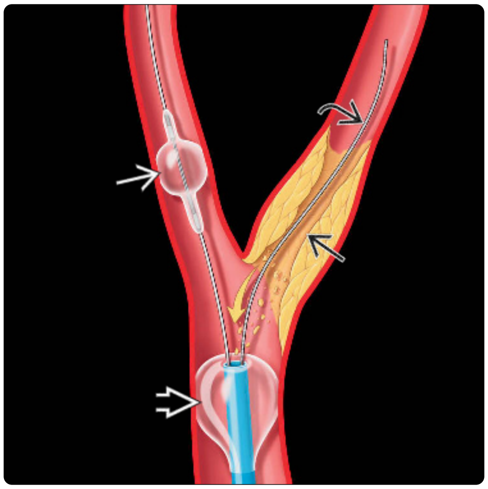
Distal Filter EPD: Carotid Stent Positioned at Stenosis



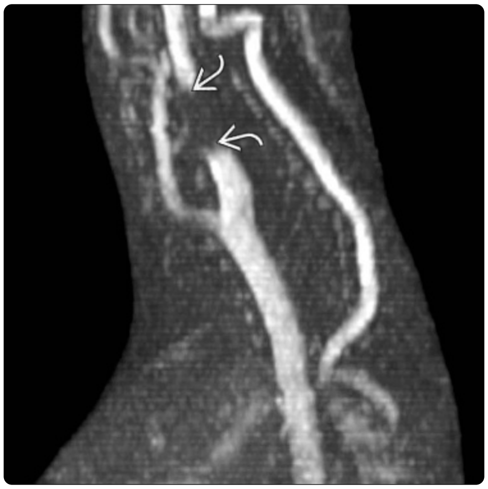
Distal Filter EPD: DSA After Carotid Stent Deployment



Proximal Flow Blockage EPD: Graphic of Deployed Protection Device

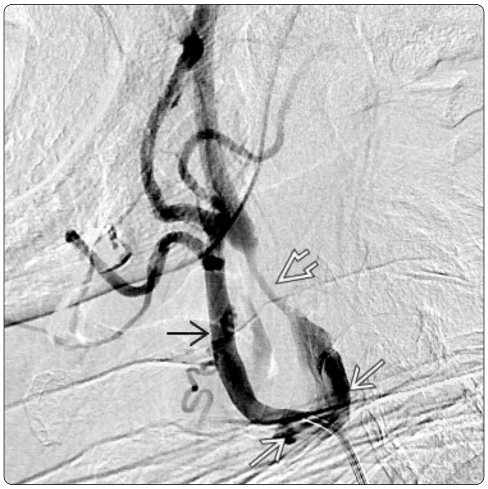


Proximal Flow Blockage EPD: Initial MR Angiography Imaging Evaluation

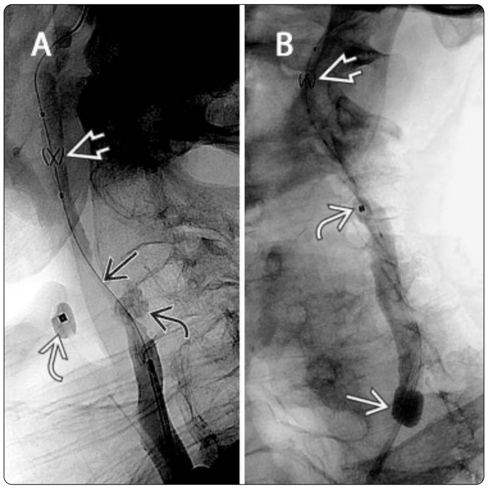


(Left) *Graphic shows a proximal flow blockage EPD. An occlusion balloon ⇨ at the distal end of a sheath is inflated in the CCA below the ICA stenosis →. A 2nd smaller balloon → is inflated in the ECA. A guidewire ↪ placed via the sheath is advanced across the stenosis while the sheath is aspirated. This reverses ICA flow and captures any embolic debris (yellow arrow).* **(Right)** *Vessel size can be measured on preprocedure images. MR can overestimate stenosis severity, as in this case, where a segment of the ICA appears occluded ↪.*

Proximal Flow Blockage EPD: Initial Selective Carotid DSA

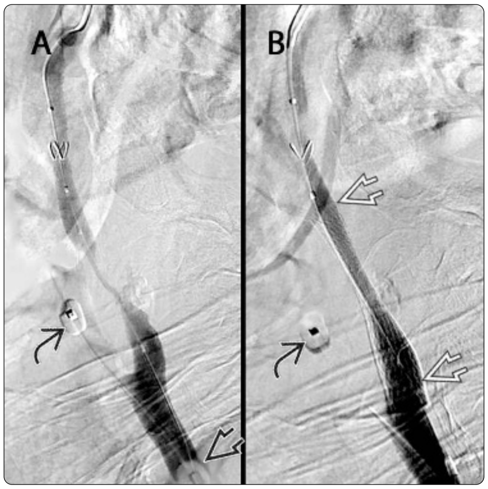


Proximal Flow Blockage EPD: Fluoroscopy of Deployed Protection Device

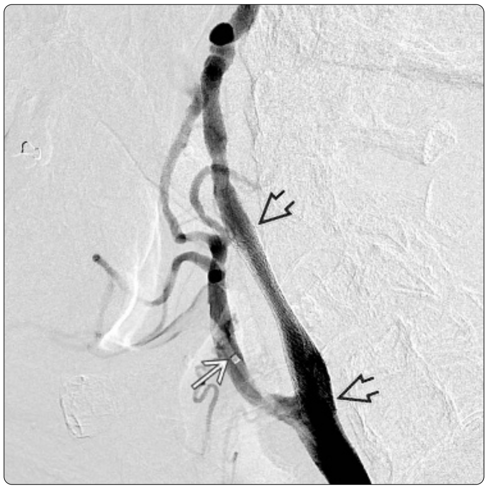


(Left) *Selective common carotid DSA shows a severe stenosis ⇨ of the ICA distal to the CCA bifurcation → and a patent ECA →. This anatomy is ideal for using a proximal flow blockage EPD.* **(Right)** *Images in (A) lateral and (B) oblique projections show that the ECA ↪ and CCA balloons → are inflated, and an Emboshield NAV^6 ⇨ filter has also been deployed for additional embolic protection. Contrast injection shows the guidewire crossing the stenosis → and a large calcified plaque ↪ at the proximal end of the stenosis.*

Proximal Flow Blockage EPD: ICA Stent Placement



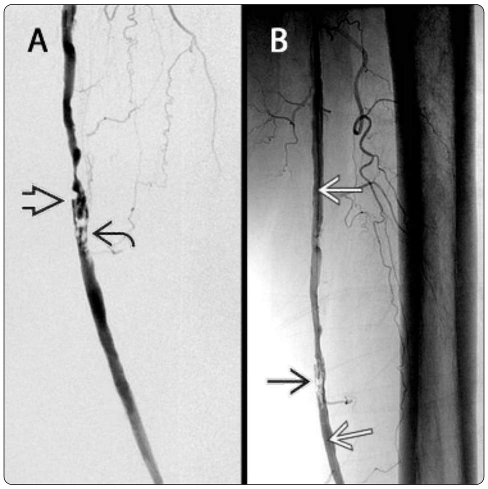
Proximal Flow Blockage EPD: DSA Following Stent Placement



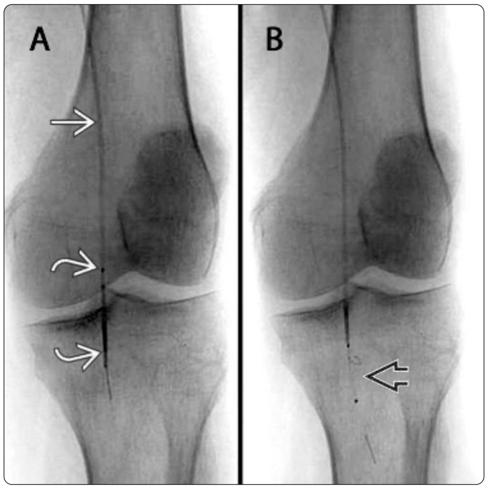
(Left) *DSA (A) prior to and (B) during carotid artery stenting ⇨ shows the ECA ↪ and CCA ⇨ balloons inflated. When the stenosis is crossed with a guidewire, catheter, or device, the balloon sheath is aspirated, thus reversing flow in the ICA to prevent any intracranial embolization.* **(Right)** *CCA completion DSA shows a well-expanded stent ⇨ in satisfactory position with no residual stenosis. The Emboshield NAV^6 filter has been removed, but the deflated ECA occlusion balloon → remains in place.*

(Left) *DSA of the left superficial femoral artery shows (A) an eccentric and irregular stenosis ⇨ with filling defects ↪ that may represent thrombus or friable atheroma. (B) A guidewire ➡ has been advanced across the lesion ⇨.* **(Right)** *Fluoroscopic image shows deployment of a Spider EPD. After crossing the lesion with the guidewire, (A) the sheath ➡ containing the collapsed EPD ➦ is advanced over the wire and positioned in the desired location. (B) The sheath is retracted, and the self-expanding device ⇨ is deployed in the artery.*

Peripheral Arterial Intervention: Atherectomy With Embolic Protection

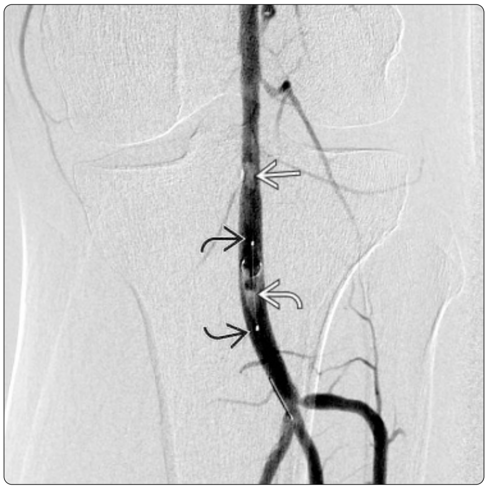


Peripheral Arterial Intervention: Deployment of Spider EPD

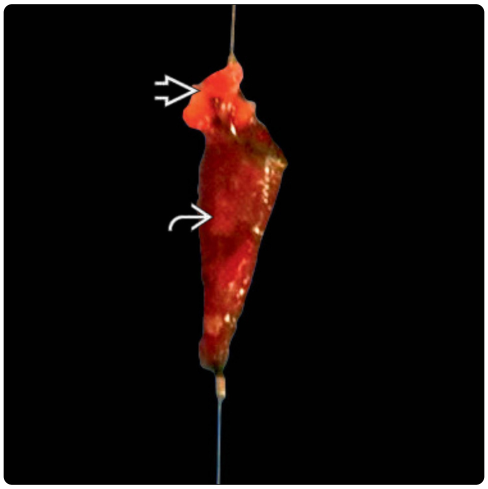


(Left) *DSA obtained during atherectomy of the SFA stenosis shows the Spider embolic protection device ↪ in the popliteal artery. A large filling defect ➦ within the EPD represents embolic debris. A 2nd filling defect ➡, more cephalad in the popliteal artery, has not yet been captured in the device.* **(Right)** *Photograph obtained after EPD removal shows a large burden of atheroembolic debris filling ➦ the Spider device. Debris ➡ also extends outside of the EPD due to the large embolic volume that occurred during intervention.*

Peripheral Arterial Intervention: Embolic Debris Trapped by EPD

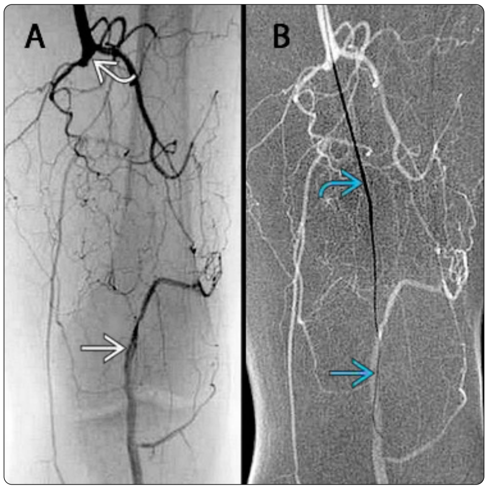


Peripheral Arterial Intervention: Embolic Debris Trapped by EPD

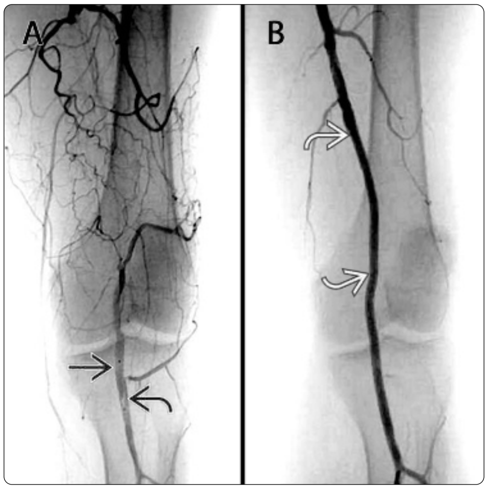


(Left) *An EPD may be used during arterial thrombolysis to prevent embolization of lysed thrombus. The occlusion must be crossed before EPD deployment. (A) There is acute SFA occlusion ➡ with popliteal artery reconstitution ➡. (B) Using roadmap guidance, the occlusion was crossed with a guidewire → and catheter ↪.* **(Right)** *(A) After crossing the lesion, a Spider EPD → was placed distally, and thrombolysis was initiated. A filling defect ↪ in the EPD represents embolic debris. (B) After thrombolysis, a covered stent ➦ was placed.*

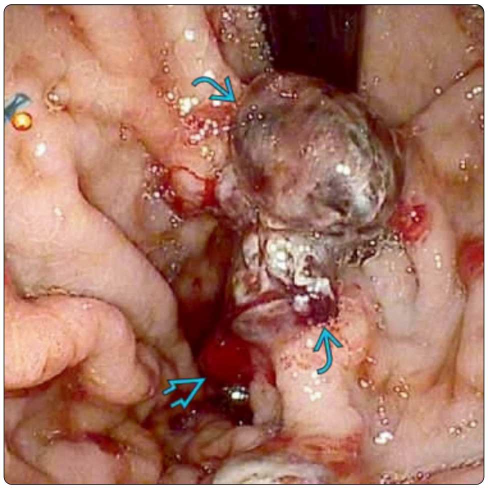
Embolic Protection During Thrombolysis: Crossing Acute Arterial Occlusion



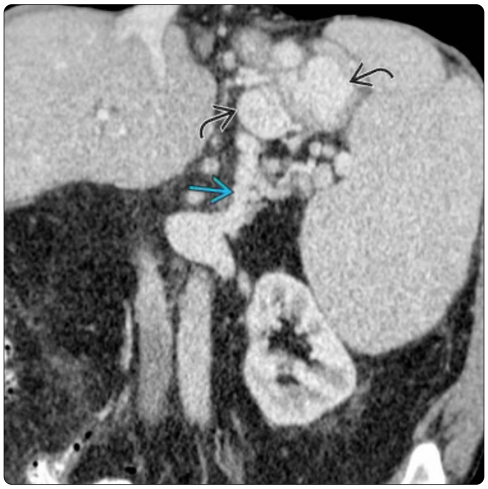
Embolic Protection During Thrombolysis: Embolic Debris Trapped by EPD



Balloon Occlusion Embolic Protection During Variceal Embolization: Endoscopy

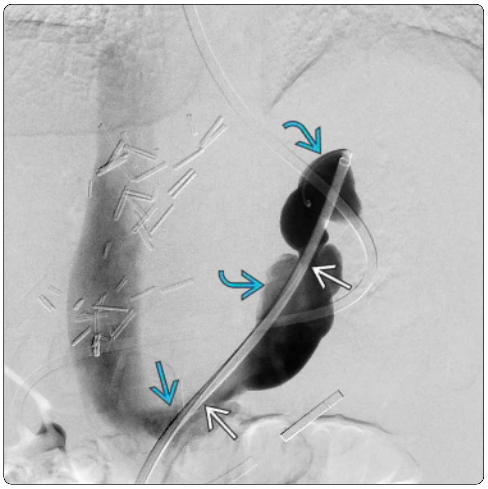


Balloon Occlusion Embolic Protection During Variceal Embolization: CECT

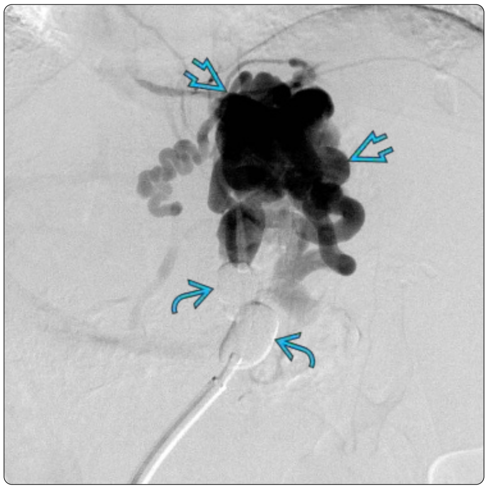


(Left) *Upper endoscopy image obtained in a patient with a history of portal hypertension and repeated episodes of hematemesis demonstrates large gastric varices ↪ with areas of adherent clot ⇨. These were isolated varices that were located mainly in the gastric fundus with no obvious esophageal varices seen.* **(Right)** *Coronal image from a CECT confirms the large isolated gastric varices ↪ that were seen endoscopically and also demonstrates the presence of a gastrorenal shunt → in the retroperitoneum.*

Balloon Occlusion Embolic Protection: Venography of Gastrorenal Shunt

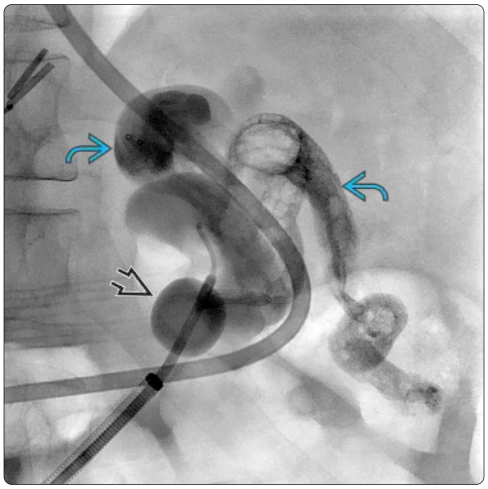


Balloon Occlusion Embolic Protection: Venography of Gastric Varices

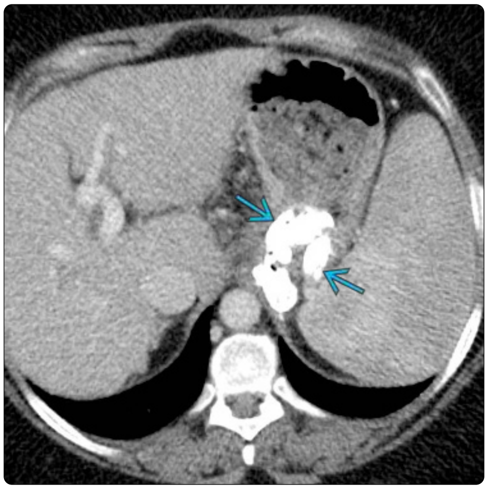


(Left) *BRTO of the gastric varices was felt to be the best treatment option for the patient. A balloon occlusion catheter ➡ was advanced through the left renal vein →, and the tip was placed in the gastrorenal shunt ↪.* **(Right)** *The balloon ↪ was inflated, and contrast was injected, opacifying the varices ⇨.The balloon acts as an EPD that protects the systemic venous circulation from reflux of any embolic material during administration of the sclerosant.*

Balloon Occlusion Embolic Protection: Administration of Sclerosant Solution



Balloon Occlusion Embolic Protection: Follow-Up CT After Treatment



(Left) *The sclerosant ↪ is slowly injected under fluoroscopic monitoring with balloon inflated ⇨. Various sclerosing agents can be used, including ethanolamine oleate iopamidol, sodium tetradecyl sulfate, and polidocanol, in either liquid or foam consistency. N-butyl-cyanoacrylate (glue) and absolute ethanol have also been used as liquid sclerosants.* **(Right)** *CECT obtained following BRTO treatment shows high-density embolic agent → within the gastric varices in the desired location.*

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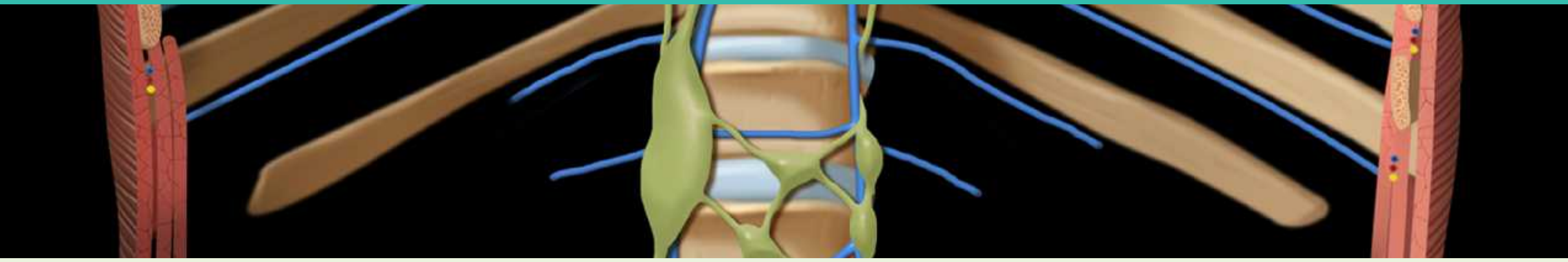
SECTION 2

Venous, Portal, and Lymphatic Procedures



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KEY FACTS

TERMINOLOGY

- Seldinger technique: Needle puncture with subsequent guidewire introduction into vessel through needle; needle exchanged for sheath/catheter over wire
- Available access routes
  - Internal/external jugular vein
  - Common femoral vein
  - Subclavian vein
  - Popliteal vein
  - Greater/lesser saphenous vein
  - Translumbar IVC
  - Transhepatic IVC or portal vein

PREPROCEDURE

- Review indications to determine best route of access
- Review prior imaging for patency of planned route of access

PROCEDURE

- US guidance is preferred during needle access
  - 21-g needle for 0.018" wire/micropuncture
  - 18-g needle for direct 0.035" system
- Confirm venous blood return through needle
- Introduce wire fluoroscopically
  - Place microaccess sheath; upsize wire to 0.035"
- Place desired sheath/catheter

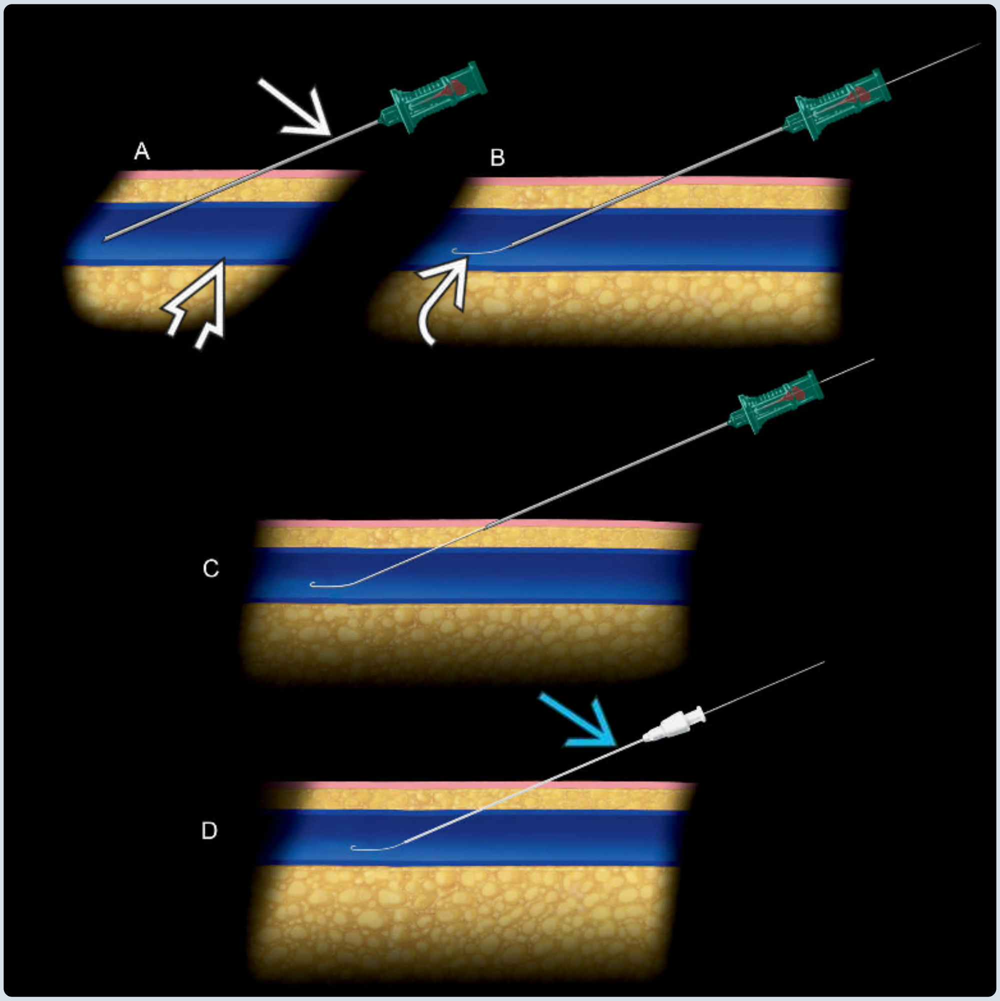
POST-PROCEDURE

- Obtain hemostasis
- Observe for location-specific potential complications

OUTCOMES

- Nearly 100% success rate for image-guided access
  - 5-13% failure rate for blind access
- Complications: Pneumothorax, arterial puncture, air embolism, venous perforation

Venous Access



Graphic shows venous access technique utilizing Seldinger technique and microaccess kit: (1) Access needle ➡ is inserted into the target vein ⇨; (2) microwire ↪ is advanced through the needle into the vein lumen; (3) needle is removed over the wire; (4) and microaccess sheath ⇨ is inserted over the wire into the vein lumen.

TERMINOLOGY

Definitions

- Seldinger technique: Needle puncture with subsequent guidewire introduction into vessel through needle; needle exchanged for sheath/catheter over wire
  - Available access routes
    - **Jugular vein access**: Most frequent access site for procedures and catheter placements
      - Internal jugular typically preferable to external jugular
      - External jugular often enlarged in cases of internal jugular occlusion
      - Right is preferable to left
      - Shortest distance to central veins for catheter placement
      - Most direct path to superior vena cava (SVC), right heart and pulmonary vasculature
      - Direct path to inferior vena cava (IVC)
      - Anatomically most suitable route for hepatic vein access
    - **Common femoral vein access**: 2nd most common after IJ access
      - Can be accessed without US guidance by targeting medial to arterial pulse
      - Safe access for placement of central venous & hemodialysis catheters, but higher catheter infection rates vs. jugular venous access
      - Preferable access for some procedures (e.g., May-Thurner, iliocaval thrombolysis, antegrade internal jugular access, e.g., petrosal sinus sampling)
      - Extracorporeal oxygenation
    - **Subclavian vein access**: Least preferred site for upper central access
      - Highest rate of pneumothorax
      - Prone to symptomatic stenosis/thrombosis
      - Postprocedure stenosis may affect dialysis venous outflow from upper extremity fistula/graft if required in future
      - Vein is nonpalpable and cannot be compressed to secure hemostasis
    - **Basilic/cephalic/brachial vein access**
      - Most common access site for peripherally inserted central catheter (PICC)
      - Favorable procedure access for venous recanalization (e.g., Paget-Schroetter)
    - **Popliteal vein access**
      - Favorable for diagnostic lower extremity/pelvic venogram
      - Access site for iliofemoral deep vein thrombosis (DVT) thrombolysis procedures ± popliteal vein thrombosis
    - **Greater/lesser saphenous vein access**
      - Access site for venous insufficiency/varicose vein treatment
      - Alternative access site for DVT thrombolysis procedures for iliofemoral ± popliteal vein thrombosis
    - **Translumbar IVC access**
      - Salvage central venous access site for infusion therapy and dialysis access for patients with SVC/infrarenal IVC occlusion
      - Risk of right ureter and kidney injury
    - **Transhepatic access**
      - Central venous and dialysis access for patients with SVC/infrarenal IVC occlusion
      - Portal/mesenteric interventions

PREPROCEDURE

Indications

- Central venous access
  - Catheter insertion for infusion or exchange therapy
    - Internal jugular vein (IJV) preferred
  - Procedural access
    - Transjugular liver biopsy
    - Transjugular intrahepatic portosystemic shunt/balloon-occluded retrograde transvenous obliteration (TIPS/BRTO)
    - IVC filter insertion/retrieval
    - Treatment of occluded/stenotic central veins
    - Gonadal/pelvic vein embolization
    - Venous insufficiency/varicose vein treatment
    - Pulmonary arteriovenous malformation (AVM) embolization
    - Transvenous cardiac pacemaker/defibrillator placement
    - Extracorporeal oxygenation
  - Diagnostic venography

Contraindications

- General
  - Coagulopathy
    - Low bleeding risk: INR > 2.0; platelets < 50,000/μL
    - Moderate and high bleeding risk: INR > 1.5; platelets < 50,000/μL
  - Occlusion of targeted veins
  - Focal skin infection
- Procedure specific

Preprocedure Imaging

- Review any pertinent prior imaging study for relevant anatomy/pathology
  - NECT and CECT (neck/chest/abdomen/pelvis)
    - Preoperative CT recommended for translumbar access to confirm anatomy
  - Prior venous US studies
    - Confirm/exclude patency of access site
  - Prior angiography
    - Especially in hemodialysis patients

Getting Started

- Things to check
  - Indication: Procedure requested to determine appropriate target vein
  - History
    - Central venous catheters or DVT
      - Increased risk of occluded vein at access site or target vein
      - Hemodialysis patients are at significantly increased risk of central venous occlusion

    - Prior interventions/surgeries
  - Physical examination of access site
    - US confirmation of vessel patency
    - Focal skin conditions (e.g., cellulitis)
    - Prior access scars (suggests access may be difficult/not possible)
  - Anticoagulant medications
    - Withhold anticoagulant/antiplatelet agents on procedure-specific basis rather than access-specific basis
      - Use caution regarding transhepatic access
  - Allergies: Iodine, latex, postprocedural tape/bandages
  - Laboratory results: Procedure-specific
  - Limit oral intake for procedures requiring moderate sedation
    - NPO for 8 hours if sedation planned (hospital protocol specific)
    - Take any oral medications with sips of water
  - Obtain informed consent: Discuss possibility of vascular injury, pneumothorax (IJ and subclavian routes), infection, hematoma/bleeding, air embolism, unsuccessful procedure
- Medications
  - Local anesthetic
  - Sedative/analgesics, antithrombotics, antibiotics on procedure-specific basis
    - On individual basis as recent publications do not support widespread prophylactic use of antibiotics
- Equipment list
  - Fluoroscopy equipment
  - US equipment
    - 5- to 8-MHz US probe, cover, gel
  - Elements for maximum sterile barrier technique
    - Sterile gown and gloves, cap, mask, eyewear
  - Preparatory solution for cutaneous antisepsis
    - 2% chlorhexidine
    - Povidone-iodine and 70% alcohol
  - Sterile barrier drape
  - Microaccess set
    - 21-g access needle (long for transhepatic and translumbar technique)
    - 0.018" microwire
    - Microaccess dilator/sheath combination
  - 0.035" guidewires and short angled catheter may be required if there is stenosis or tortuous target vein anatomy
  - Scalpel: #11 blade
  - Dilators
  - Sheath

PROCEDURE

Patient Positions/Location

- Best procedure approach
  - Internal jugular vein access
    - Patient supine
    - Head turned away from access site
  - Common femoral vein access
    - Patient supine; both lower extremities extended
    - Access over lower 1/3 of femoral head
  - Subclavian vein access
    - Patient supine; head turned away from target vein
    - Access below clavicle, over 1st rib
  - Basilic/cephalic/brachial vein access
    - Patient supine; arm extended, abducted
    - Access above antecubital fossa
  - Popliteal vein access
    - Patient prone; access at popliteal fossa
  - Greater/lesser saphenous vein access
    - Patient supine [greater saphenous vein (GSV)]; prone [lesser saphenous vein (LSV)]
    - Access GSV above or below knee; LSV below knee
  - Translumbar IVC access
    - Patient is in prone or posterior oblique prone position
    - Right paraspinal access site
    - Needle enters skin just above right iliac crest and angled toward L2-L3 disk space ~ 1 cm lateral to spine
  - Transhepatic venous access
    - Patient supine
    - Right flank intercostal or anterior subcostal access
      - IVC access via hepatic vein
      - Transparenchymal approach directly into IVC
    - Access at abdominal midline preferable for IVC catheterization because of shortest distance through hepatic parenchyma
  - Transhepatic portal venous access
    - Patient supine or left oblique position
    - Access with US or fluoroscopic guidance, per operator experience/comfort
    - Right portal vein
      - Right portal vein is preferred for most interventions
      - Inferior approach to avoid pleura
      - Intercostal or anterior subcostal access
    - Left portal vein
      - Anterior midline access for left portal vein

Procedure Steps

- **General**
  - Connect patient to hemodynamic monitoring
    - Blood pressure, EKG, oxygen saturation
  - Cleanse skin with preparatory solution
    - Prepare larger area than expected
  - Place sterile drapes to isolate sterile field
- **Guidance**
  - **US guidance**
    - Allows real-time visualization of vein, artery, and needle
      - Highest rate of successful access
      - Decreased risk of access site complications
      - Decreased risk of artery puncture
    - Place sterile cover on probe
      - Apply gel on probe crystal
      - Exclude trapped air under probe cover
      - Apply sterile gel externally on sterile probe cover
    - Scan to identify target vein and adjacent arterial structures
      - Pressure with transducer should easily compresses vein
      - Artery is less compressible, pulsatile

      - If in doubt, color Doppler/duplex or spectral Doppler can be used for confirmation
    - Confirm patency of target vein
    - Choose axial or longitudinal plane of scan relative to target vein
    - **Axial US with needle lateral to target vein** (image perpendicular to target vein)
      - Vein seen in cross section, possibly off to one side
      - Needle inserted parallel to transducer and remains in plane of scan
      - Needle enters from side of screen and seen in entire length
      - Needle indents side of vein during access
      - Can be challenging to determine needle depth
    - **Axial US with needle over target vein** (image perpendicular to target vein)
      - Vein seen in cross section in middle of screen
      - Needle inserted directly over target vein, in parallel with target vein, accessing skin at mid-point of transducer
      - Needle angled to plane of scan and only segmentally visualized
      - Needle indents top of vein during access
      - Can be challenging to advance wire down vessel lumen
    - **Longitudinal US with needle over target vein** (image parallel to target vein)
      - Transducer parallel over target vein
      - Needle inserted parallel to transducer and remains in plane of scan
      - Needle enters from side of screen and seen in entire length
      - Needle inserted directly over target vein
      - Needle indents top of vein during access
      - Can be challenging to track needle and vessel simultaneously
  - **Venography guidance**
    - Used if US cannot demonstrate target vein
    - Avoid if contrast allergy or renal dysfunction
      - IV angiocatheter/butterfly needle in vein giving inflow to target vein (e.g., hand, antecubital vein)
      - Inject contrast to opacify target vein
      - Center fluoroscopy, magnify target, collimate
      - Advance needle under fluoroscopy to target vein
  - **CT guidance**
    - May use for translumbar access in some cases
    - Does not allow real-time needle/wire advancement
  - **Anatomic landmarks**
    - Use known anatomic relationships to palpable arterial or osseous structures to locate vein
    - Used mostly for common femoral vein or subclavian access
- **Internal jugular vein access**
  - Identify internal jugular vein
  - Determine "low" or "high" access
    - Low access
      - Preferred for tunneled catheters, port catheters
      - Access from side (laterally) allows gentle curvature of tunneled catheters and ports
      - Place transducer just above clavicle transverse and slightly lateral relative to vein
    - High access
      - Preferable for nontunneled catheters and most interventions
      - Access from top (anteriorly) generally easiest
      - Place transducer superior to clavicle, axial over IJV/perpendicular to target
  - Magnify target vein by decreasing US depth of view
  - Localize position of adjacent carotid artery (avoid it)
  - Adjust gain to have clear view of venous and arterial walls
  - Administer local anesthetic to skin over target vein
    - Adequate cutaneous wheal allows elevation of skin from vein in thin patients for safe skin incision
  - Introduce 21-g micropuncture needle
    - Angle probe to visualize needle
  - Identify needle tip with US
    - **Caution**
      - Chose needle trajectory away from artery; prevents inadvertent arterial puncture
      - Do not aim needle steeply inferiorly; reduces risk of pneumothorax
  - Advance so needle tip deforms lateral vein wall
    - Continue advancing so needle "tents" vein wall
    - After tenting wall, advance needle meaningfully & rapidly with "pop" until wall releases, needle enters vein lumen
    - Visualize needle tip within lumen
  - Confirm blood return at needle hub
    - If no spontaneous return, may try aspiration
    - If no aspiration, inject saline to clear needle and then aspirate again
    - Venous blood dark red; arterial blood bright red
  - Introduce 0.018" guidewire through needle
    - Should not encounter resistance to wire passage
    - If encounter resistance to advancing wire, turn needle to change bevel direction, try readvancing wire with slight spinning motion
    - If persistent resistance, withdraw wire into needle, withdraw needle slightly, try readvancing wire
      - Consider removing wire and aspirating blood to confirm location within vessel
      - Consider changing microwire (e.g., gold-tipped Nitrex, Covidien, UK)
      - **Caution**: If resistance met pulling wire back, stop and remove needle and wire as unit; prevents shearing portion of wire with sharp needle bevel
  - Fluoroscopically monitor guidewire insertion
    - Advance into SVC near cavoatrial junction
    - Wire must stay to right of midline; wire left of midline may indicate arterial placement, persistent left SVC, extraluminal location
    - If wire will not advance centrally, consider possible central venous tortuosity or occlusion
      - Venography may be performed via access needle/microaccess sheath to assess IJ/central venous patency
      - If IJ occluded inferiorly, consider external jugular access

    - ◻ If central veins occluded, consider alternate access sites
  - Make shallow skin nick with #11 scalpel
    - Incision can be made prior to or after creating access
  - Remove needle, introduce transitional dilator (microaccess sheath) over 0.018" guidewire
  - Remove inner dilator and microwire from sheath
    - **Caution**: Do not leave needles/sheaths/catheters open to air; occlude with thumb/digit, clamp, stop-cock, or wire to prevent air embolism
  - Introduce 0.035" guidewire, advance into SVC, further advance into IVC for stability
    - Monitor guidewire passage fluoroscopically
    - Guidewire in atrium may cause cardiac arrhythmia; retract/reposition guidewire if cardiac arrhythmia induced
  - Remove microaccess sheath
  - Perform fascial dilation under fluoroscopy, if required
    - Gentle traction to wire will straighten wire and prevent kinking
    - **Caution**: Do not advance dilator past end of guidewire; may result in life-threatening vascular injury, mediastinal hemorrhage, pericardial tamponade
  - Introduce appropriate sheath/catheter over wire under fluoroscopy
    - Gentle traction to wire will improve trackability of catheter/sheath
    - Align sheath or catheter with venous axis to avoid wire kinking
- **Common femoral vein access**
  - Anatomic landmarks for access
    - Palpate/localize common femoral artery (CFA)
    - Common femoral vein lies medially and posteriorly to CFA
  - For US-guided access, steps are similar to IJV access
    - CFA noncompressible and pulsatile
    - Identify GSV to avoid inadvertent puncture
    - Place transducer perpendicular over common femoral vein
  - Introduce 21-g micropuncture needle
  - Confirm blood return at needle hub
    - Nonpulsatile
    - If no spontaneous return, may try aspiration
  - Introduce 0.018" guidewire through needle into lumen
  - Fluoroscopically monitor guidewire insertion
    - Pulsatile movement of wire tip or wire crossing midline may indicate arterial placement
  - Make skin nick with #11 scalpel
  - Exchange needle for microaccess sheath
  - Remove inner dilator and microwire from sheath and introduce 0.035" guidewire into IVC
    - Fluoroscopically monitor guidewire insertion
    - Wire should remain to right of midline
  - Remove microaccess sheath and perform fascial dilation, if required
  - Introduce appropriate sheath/catheter over wire for planned procedure
  - Refer to internal jugular access above as needed
- **Subclavian vein access**
  - Anatomic landmarks for access
    - Consider placing patient in Trendelenburg position
    - Insert needle 1 cm lateral and 1 cm inferior to junction of middle/medial 1/3 of clavicle
    - Aim needle toward sternal notch
    - Advance needle under inferior clavicular margin while aspirating needle; watch for blood return
    - Remove syringe, insert guidewire; place sheath
  - Venography for access
    - Inject contrast via peripheral IV, opacify vein
    - Puncture vein below clavicle where vein crosses 1st rib; protects from pneumothorax
  - US guidance for access
    - Same principles as jugular venous access; see internal jugular access above as needed
    - Subclavian vein lies anterior and inferior to subclavian artery
- **Basilic/cephalic/brachial vein access**
  - US guidance preferred for obtaining access
  - Avoid excessive manipulations to prevent vasospasm
  - Consider distending veins
    - Place tourniquet high in axilla
  - Identify arm veins to determine appropriate target
    - Patent vein easily compressible
    - Artery pulsatile, poorly compressible
  - Place transducer perpendicular over target vein
  - Introduce 21-g micropuncture needle
    - Identify needle tip with US
  - Advance so needle tip deforms anterior vein wall
    - "Jabbing" motion into venous lumen
    - Look for blood return at needle hub
  - Introduce guidewire through needle into lumen
    - Should not encounter resistance to wire passage
    - Fluoroscopically or sonographically monitor guidewire insertion
  - Make skin nick with #11 scalpel
  - Introduce sheath/catheter over guidewire
  - Venography guidance sometimes needed
    - When US guidance unsuccessful
    - Unable to advance guidewire/catheter; suspected venous stenosis/occlusion
  - Same principles as jugular venous access; see internal jugular access above as needed
- **Popliteal vein access**
  - US guidance preferred for obtaining access
    - Vein lies posterior and lateral to popliteal artery (on top of artery when prone)
    - High frequency of anatomic variations: Duplication, high junction, etc.
  - Identify lesser saphenous vein
  - Remainder of procedure similar to basilic vein access
- **GSV/LSV vein access**
  - US guidance preferred for obtaining access
  - Consider maneuvers to distend target vein
    - Reverse Trendelenburg position
    - Tourniquet above target vein
  - Remainder of procedure similar to basilic vein access
- **Translumbar venous access**
  - Fluoroscopic access to infrarenal IVC using anatomic landmarks

    - Right paraspinal access site 8-10 cm from midline just above iliac crest
  - Advance long 21-g needle toward L2-L3 disk space staying just lateral to spine
    - Align C-arm in line with needle to confirm satisfactory trajectory
    - Oblique angle minimizes changes of catheter kink at IVC access site
  - Loss of resistance may be felt when IVC is entered
    - Needle pulsations may indicate intraaortic position; retract needle while aspirating
  - Aspirate blood
  - Introduce 0.018" guidewire through needle into lumen
    - Fluoroscopically monitor guidewire insertion
  - Make skin nick with #11 scalpel
  - Exchange needle for microaccess sheath
  - Remove inner dilator and microwire from sheath and introduce stiff 0.035" guidewire through IVC and right atrium to SVC
    - Fluoroscopically monitor guidewire insertion
    - Wire should remain to right of midline
  - Remove microaccess sheath and perform fascial dilation, if required
  - Introduce appropriate sheath/catheter over wire for planned procedure
  - If femoral vein patent, introduce catheter into IVC
    - Catheter is fluoroscopic target for access needle
  - US-guided access may be performed in pediatric patients
  - CT-guided access
    - Right paravertebral approach; aimed at IVC
    - Typically enter IVC below renal veins
    - Will not have pulsations transmitted to needle
    - May be done as first step to create venous access with catheter insertion performed under fluoroscopy
- **Transhepatic central venous access**
  - US guidance is preferred
    - Either hepatic IVC or hepatic vein can be selected for access
  - Advance long 21-g needle into IVC or hepatic vein
  - Aspirate blood
    - Contrast injection can be used to confirm needle position
  - Exchange needle over 0.018" microwire for microaccess sheath
  - Advance stiff 0.035" guidewire into SVC
  - Remove microaccess sheath and perform fascial dilation, if required
  - Introduce appropriate sheath/catheter over wire for planned procedure
- **Transhepatic portal venous access**
  - US guidance
    - Right or left portal vein can be accessed with long 21-g needle under direct guidance
    - Aspirate blood
      - ☐ Use contrast injection to confirm needle position
    - Exchange needle over 0.018" microwire for microaccess sheath
    - Exchange microwire for 0.035" guidewire
    - Remove microaccess sheath and perform fascial dilation, if required
    - Introduce appropriate sheath/catheter over wire for planned procedure
  - Fluoroscopic guidance
    - Advance long 21-g needle toward porta hepatis
    - Slowly withdraw needle while injecting contrast until hepatic vessel is opacified
      - ☐ Slow hepatopetal flow confirms portal vein catheterization
      - ☐ Hepatofugal flow in portal hypertension
    - Rest of procedure is similar to US-guided access

POST PROCEDURE

Things to Do

- Remove access sheath/catheter/wire
- Hold digital pressure until hemostasis
  - Usually 2-5 minutes
  - May need to elevate head of bed in patients with high central venous pressure after upper central venous access
- Close skin incision
  - Glue; subcuticular suture; bandage; Steristip (3M, St. Paul, MN)
- Apply sterile dressing to access site
- Watch access site for bleeding or hematoma
  - Particular attention to access sites that may be covered by cloths or bedsheets (femoral, popliteal, etc.)
- Bed rest
  - Elevate head of bed for upper central venous access for bed-bound patients or patients recovering from sedation
    - Decreases venous pressure at access site
    - Decreases chances of bleeding/hematoma
    - **Caution**: Elevating head of bed in patient with nonoccluded upper venous access may increase risk of venous air embolism
  - 2 hour bed rest for translumbar, transhepatic and femoral accesses
  - Procedure specific requirements
- If concern for pneumothorax
  - Evaluate lung fluoroscopically immediately post-procedure
  - Obtain AP upright inspiratory/expiratory chest radiographs post procedure and schedule additional chest radiographs as needed (usually every 1-4 hours or next AM)

Things to Avoid

- Arterial puncture with access needle
  - Visualize access needle tip with US
  - Do not insert dilator or sheath until certain of venous access
    - Advance wire into IVC below/above diaphragm
    - Inject contrast/DSA to confirm access site
    - Avoid injecting small air bubbles
- Losing wire
  - Keep control of wire at all times
  - Use wire of sufficient length to allow for comfortable access needle/dilator/sheath/catheter exchanges and insertions
  - Never cover wire completely with access needle/dilator/sheath/catheter

- Shearing wire
  - Never pull stuck wire; needle bevel may shear wire
  - Do not advance hydrophilic glidewire through access needle; needle bevel may shear wire coating
- Advancement of dilator or sheath past end of guidewire; possibility of vascular damage
  - Maintain sufficient length of intravascular wire
  - Fluoroscopically visualize insertion of dilator/catheter/sheath
- Air embolism
  - Keep access needles/sheaths/catheters occluded with clamps, stop-cocks or wires

OUTCOMES

Complications

- Arterial puncture
  - Incidence: 1% US-guided access, 3% blind access
- Pneumothorax
  - Incidence for subclavian access: 3-5%
- Air embolism
  - Reported incidence during central venous catheter placement: 0.13%
  - Potentially fatal
- Bleeding/hematoma
  - Incidence: 0.2%

Management of Complications

- Arterial puncture
  - Remain calm
  - Do **not** withdraw access needle/sheath/catheter until considering options
  - Treatment dependent on diameter of access device and location of access
  - Potential treatment
    - Needle: Consider removal with digital pressure until hemostasis
    - Dilator/sheath: Consider emergent conversation with vascular surgery prior to withdraw of access device
      - ☐ Surgical repair may be necessary/preferable
      - ☐ Arteriography with occlusion of inadvertent access with balloon or covered stent may be necessary/preferable
    - Carotid: Consider CTA neck if any signs of neurological impairment
  - After repair: Survey access site with US for signs of continued bleeding/pseudoaneurysm
- Pneumothorax
  - Evaluate size of pneumothorax
    - Fluoroscopically during procedure
    - AP upright chest expiratory/inspiratory radiographs immediately post procedure if needed
    - AP upright chest expiratory/inspiratory radiographs scheduled as needed
    - CT thorax as needed
  - Stable small pneumothorax can be managed conservatively
  - Moderate or increasing pneumothorax of any size; consider small bore chest tube placement
    - Attach to water seal, Heimlich valve, wall suction (-20 mm Hg)
- Air embolism
  - Turn patient left decubitus (left side down) or partial left decubitus (Durant maneuver) position and allow bed rest for 2 hours or until stable
  - Institute high-flow oxygen
  - In decompensating patients, air embolus can be aspirated via catheter
  - Cardiopulmonary resuscitation may be required with massive venous air embolism

Expected Outcomes

- If target vein patent, 99-100% success rate of venous access with US guidance
- 5-13% failure rate with blind puncture

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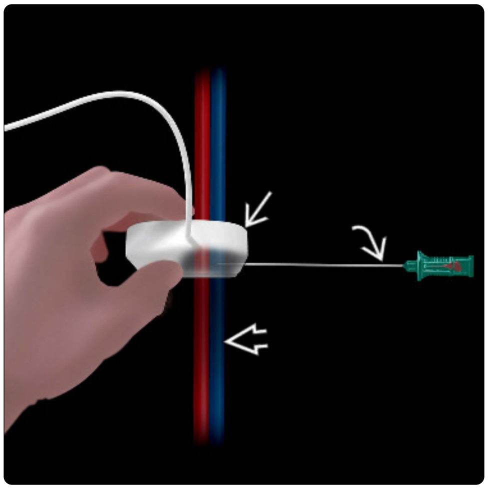
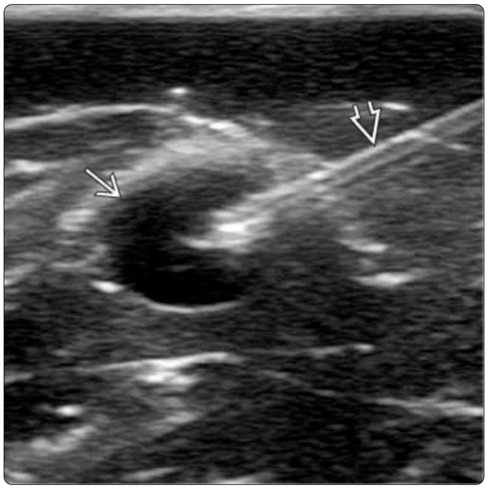
Venous Access

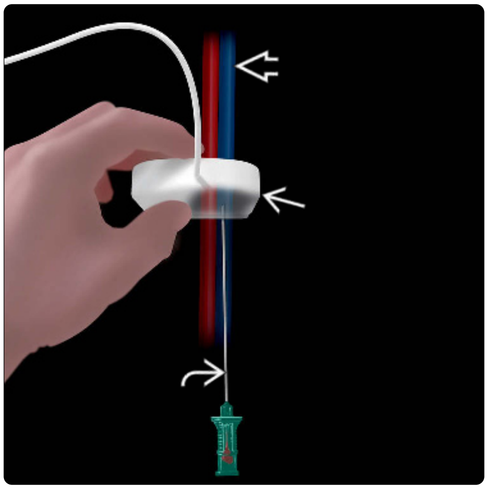


Venous Access (Image Perpendicular to Vessel)

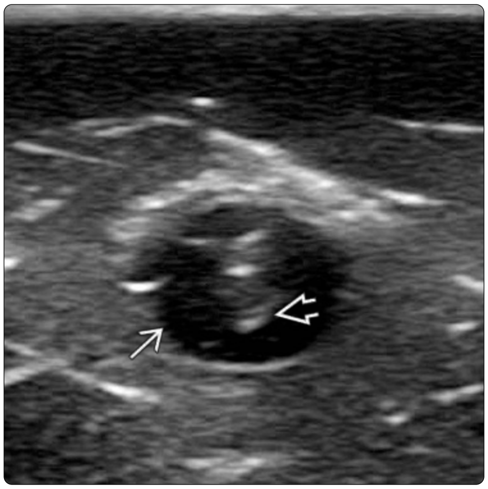


(Left) *Graphic shows US probe → positioned over the target vessel ⇨ so the vessel can be seen in cross section. The access needle ↪ is inserted perpendicular to the vessel and parallel to the plane of scan.* **(Right)** *Corresponding US image demonstrates a vessel seen in cross section →. An access needle ⇨ is inserted from the side of the vessel and seen in entire length.*

Venous Access (Axial US With Needle Over Target Vein)

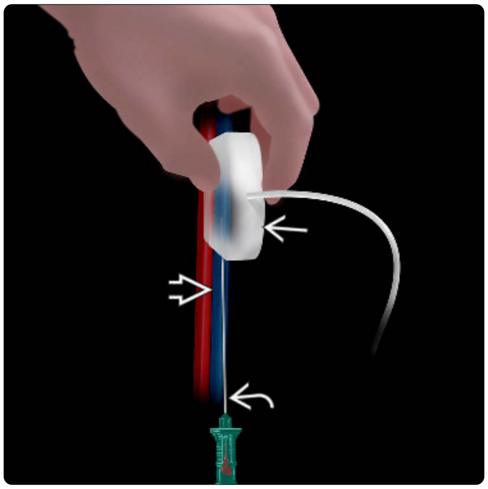


Venous Access (Image Perpendicular to Vessel)

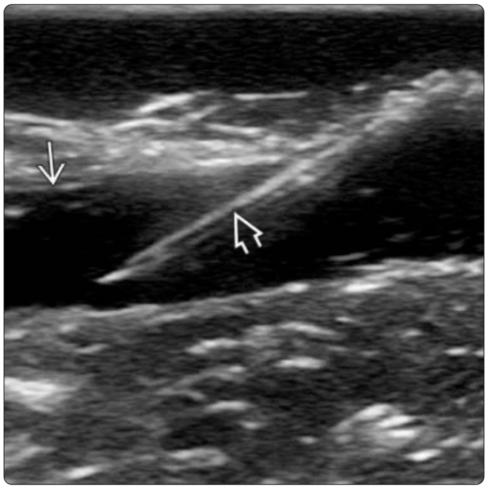


(Left) *Graphic shows an US probe → positioned over the target vessel ⇨ so the vessel can be seen in cross section. An access needle ↪ is inserted parallel to the vessel and perpendicular to the plane of scan.* **(Right)** *Corresponding US image demonstrates a vessel seen in cross section →. An access needle is inserted over the top of the vessel. The needle is angled to the plane of scan and only segmentally visualized ⇨.*

Venous Access (Longitudinal US With Needle Over Target Vein)



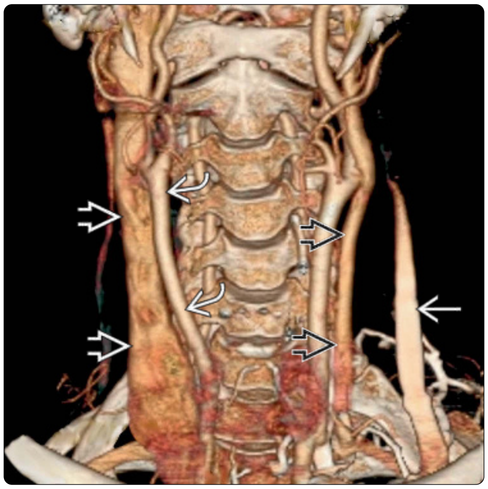
Venous Access (Image Parallel to Vessel)



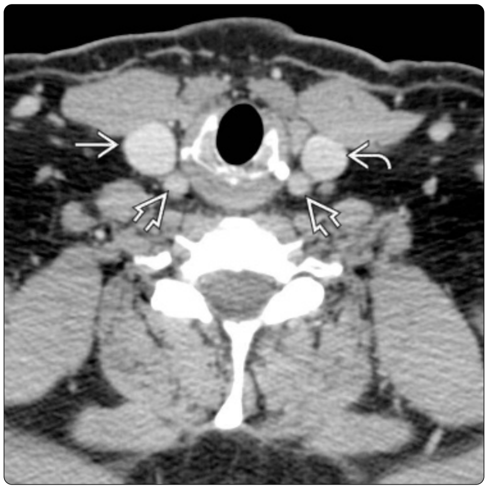
(Left) *Graphic shows an US probe → positioned over the target vessel ⇨ so the vessel can be seen longitudinally. An access needle ↪ is inserted parallel to the vessel and parallel to the plane of scan.* **(Right)** *Corresponding US image demonstrates a vessel seen longitudinally →. The access needle is inserted parallel to the plane of scan over the vessel and seen in entire length ⇨.*

(Left) *3D CT reformation shows a large right internal jugular vein ⇨ and the medially located right common carotid artery ↶. The left internal ⇨ and external → jugular veins are small. Venous asymmetry is very common.* **(Right)** *Axial CECT of the lower neck shows patent right → and left ↶ internal jugular veins located anterolateral to the respective carotid arteries ⇨.*

Jugular Venous Anatomy (3D CECT)

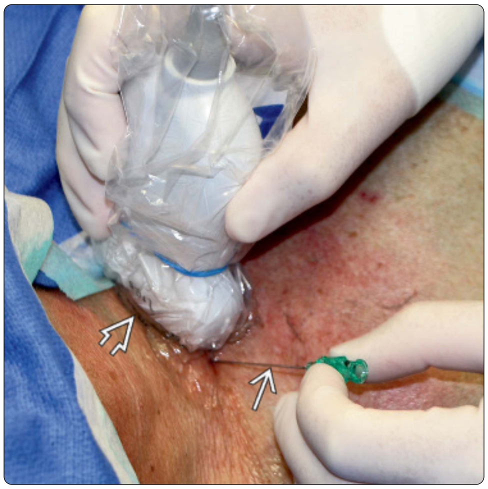


Jugular Venous Anatomy (Axial CECT)

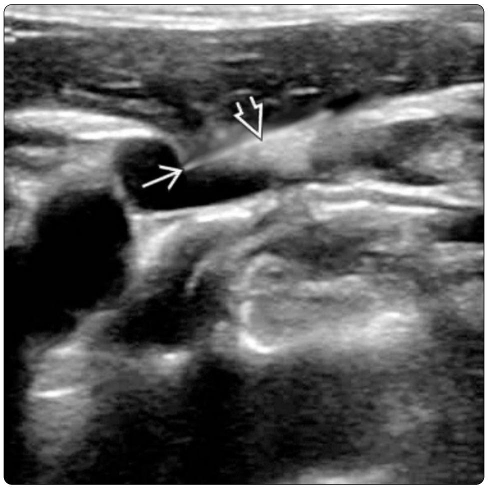


(Left) *Intraoperative photograph obtained during US-guided jugular venous access shows a microaccess needle → introduced from an anterolateral approach under US guidance ⇨.* **(Right)** *Corresponding image of US-guided venous puncture shows the echogenic needle → directed toward the internal jugular vein sidewall. The needle tip initially "tents" the vein wall ⇨ into the lumen. Continued pressure while advancing the needle allows puncture of the tented wall and lumen entry.*

Step-by-Step IJ Access (US-Guided Needle Advancement)

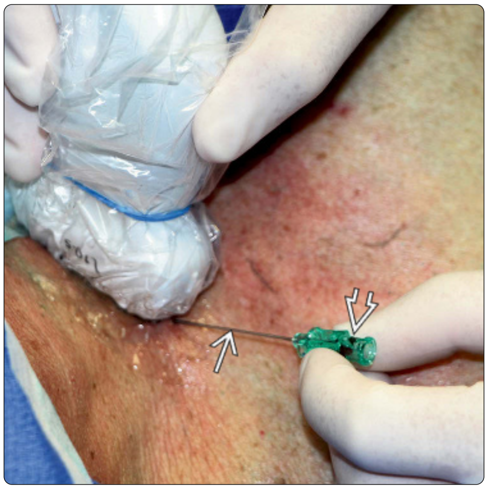


Step-by-Step IJ Access (Tenting Vessel)

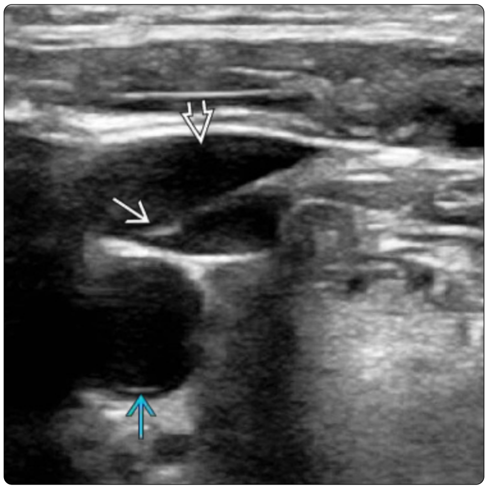


(Left) *Under US guidance, the microaccess needle → was advanced into the vein lumen. Intraluminal position of the needle tip is confirmed with blood return at the needle hub ⇨.* **(Right)** *Corresponding US image confirms position of the access needle tip → in the vein lumen ⇨. Note the carotid artery → just deep to the IJ.*

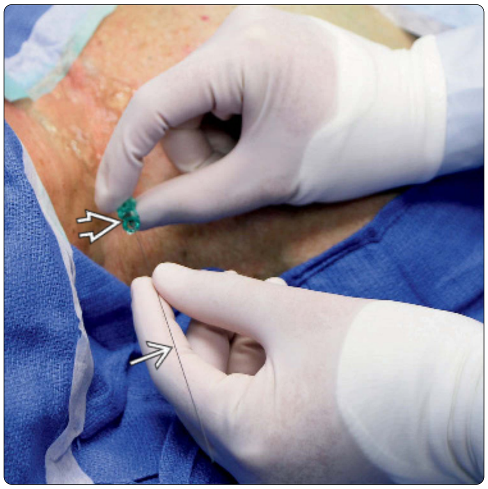
Step-by-Step IJ Access (Blood Return)



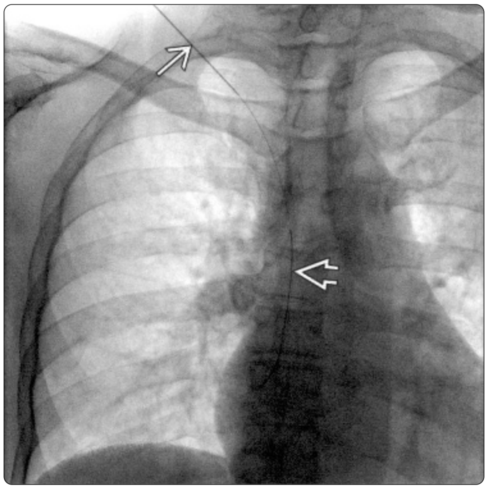
Step-by-Step IJ Access (Intraluminal Needle Tip)



Step-by-Step IJ Access (Microwire Advancement)

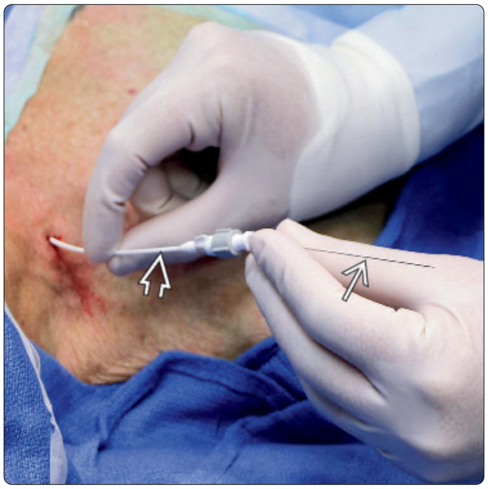


Step-by-Step IJ Access (Central Passage of Microwire)

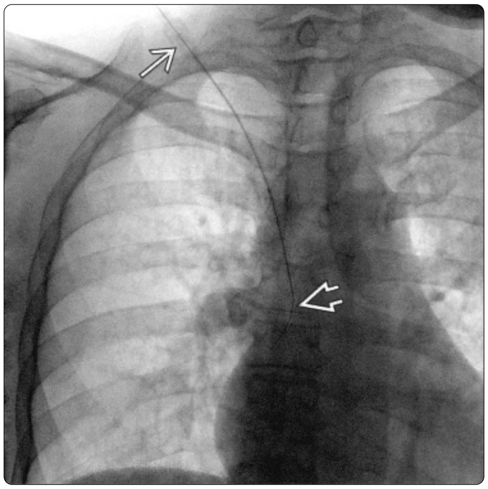


(Left) *Once the needle position within the vein lumen is confirmed, the needle ⇨ is angled slightly so that it is directed inline with the vein, and a microwire → advanced through the needle into the vein. The wire should meet no resistance.* **(Right)** *Fluoroscopic spot image demonstrates the microaccess needle → in the right internal jugular vein and the microwire ⇨ with tip in the right atrium.*

Internal Jugular Vein Access

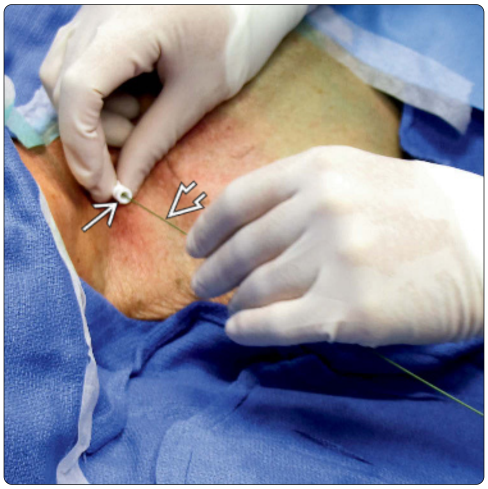


Internal Jugular Vein Access

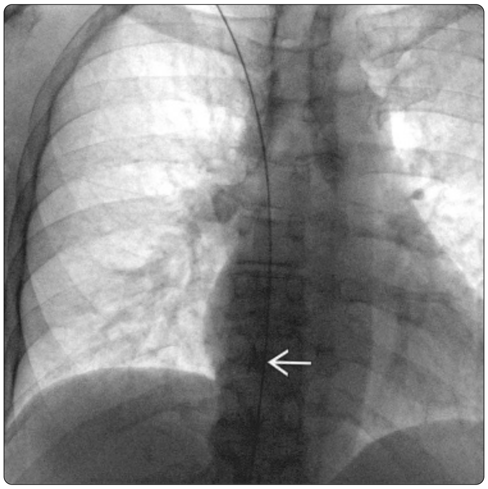


(Left) *After the microwire → is placed into the SVC, the microaccess needle is exchanged over the microwire for a microaccess sheath ⇨.* **(Right)** *Fluoroscopic spot image demonstrates the microaccess sheath → placed over the microwire ⇨. The microwire terminates at the superior cavoatrial junction.*

Step-by-Step IJ Access (Microsheath Advancement & Wire Upsize)



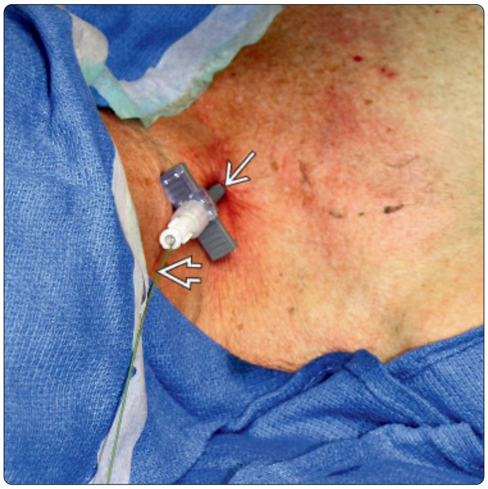
Step-by-Step IJ Access (Guidewire Advancement into IVC)



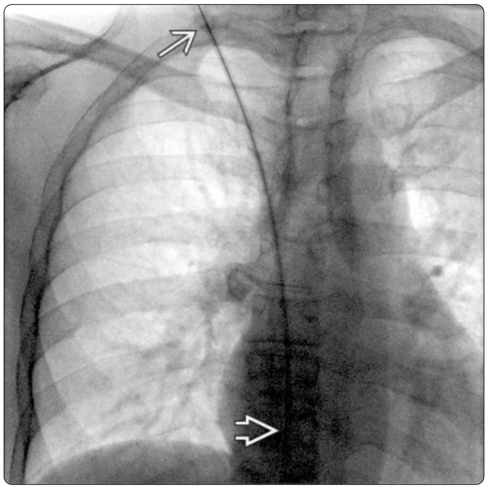
(Left) *The microsheath is advanced over the microwire. The inner dilator of the microaccess sheath → and the microwire are removed, and an 0.035" guidewire ⇨ is advanced into the vein.* **(Right)** *Fluoroscopic spot image shows that the 0.035" guidewire → placed through the microaccess sheath (not well visualized) has passed through the right atrium into the IVC.*

(Left) *Intraoperative photograph obtained after removing the microaccess sheath shows that a peel-away sheath → has been advanced into the vein over the guidewire ⇨.* **(Right)** *Fluoroscopic spot image shows proper positioning of the peel-away sheath → placed over the 0.035" guidewire ⇨.*

Step-by-Step IJ Access (Over-the-Wire Advancement of Sheath)

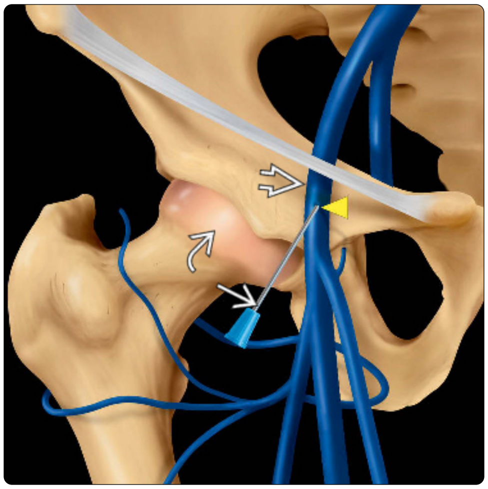


Step-by-Step IJ Access (Sheath Position Confirmation)

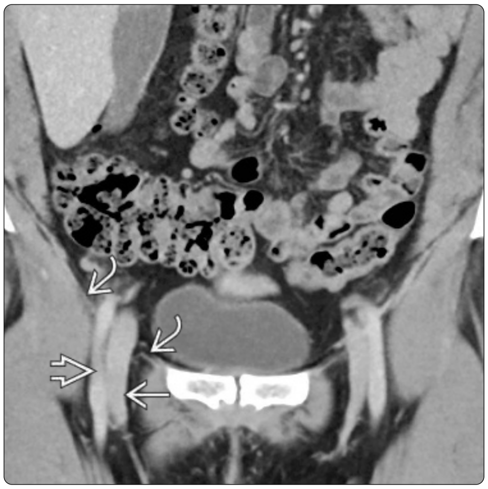


(Left) *Graphic shows an access needle → overlying the right common femoral vein ⇨ where it courses over the femoral head ↪, with the yellow arrowhead indicating the optimal point for venous puncture.* **(Right)** *Coronal CECT demonstrates femoral vein → medial and slightly posterior to the common femoral artery ⇨. Optimal location of the femoral venous access is inferior to the inguinal ligament ↪.*

Femoral Vein Access (Ideal Access Location)

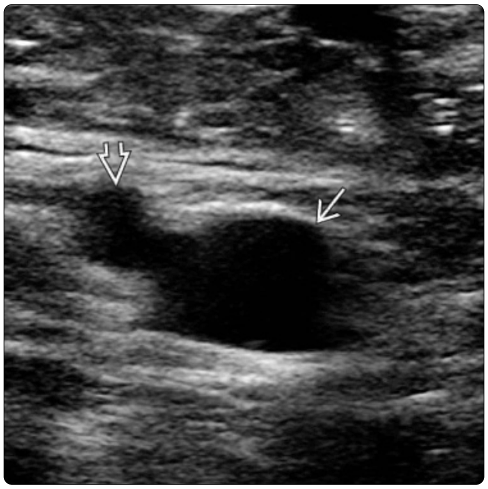


Femoral Vein Access (Anatomic Relationship of Common Femoral Artery and Vein)

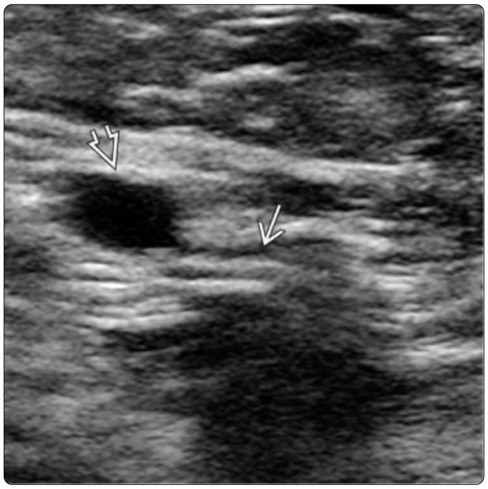


(Left) *Grayscale US demonstrates right common femoral vein → medial and slightly posterior to the right common femoral artery ⇨.* **(Right)** *Grayscale US of the right groin with compression of the same patient demonstrates compressed common femoral vein → medial to the noncompressible and pulsatile right common femoral artery ⇨.*

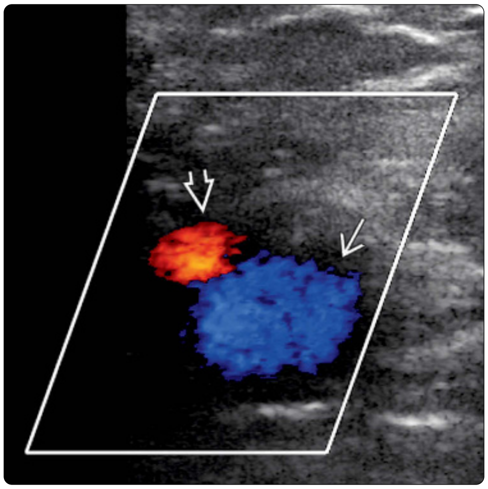
Femoral Vein Access (Axial US)



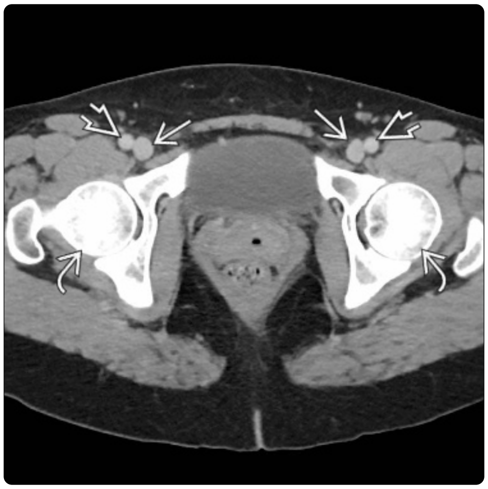
Femoral Vein Access (Axial US With Compression)



Femoral Vein Access (Axial US With Color Doppler)

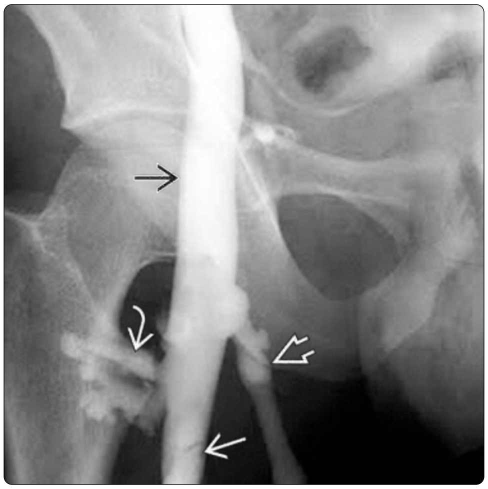


Femoral Vein Access (Axial CECT)

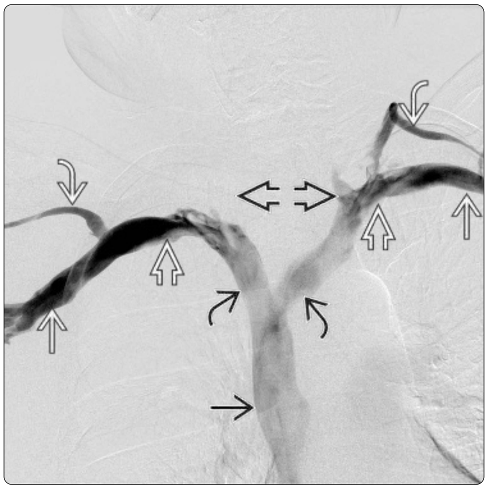


(Left) *Color Doppler US of the right groin shows the common femoral vein* ➡ *medial and posterior to the common femoral artery* ⇨*. Pulsatility of the artery usually obvious. Visualization of flow in the vein may require augmentation of the thigh.* **(Right)** *Axial CECT demonstrates optimal location for common femoral vein access at the level of the femoral head* ↪*. The common femoral vein* ➡ *lies medially and slightly posterior to the common femoral artery* ⇨*.*

Femoral Vein Access (Venography)

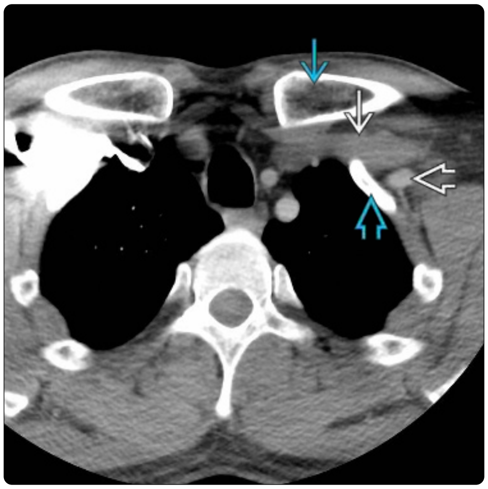


Central Venogram

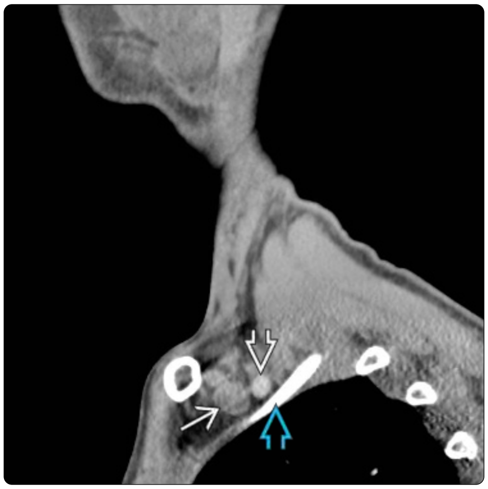


(Left) *Venogram shows the femoral vein* ➡ *in the thigh (also called the superficial femoral vein), joined by the greater saphenous* ↪ *and profunda femoral veins* ⇨ *to form the common femoral vein* ➡*.* **(Right)** *Bilateral digitally subtracted venography of the upper chest demonstrates axillary* ➡*, subclavian* ⇨*, and cephalic* ↪ *veins. Nonhomogeneous contrast opacification of the bilateral brachiocephalic veins* ↪ *and SVC* ➡ *relates to mixing artifact from the unopacified internal jugular veins* ⇨*.*

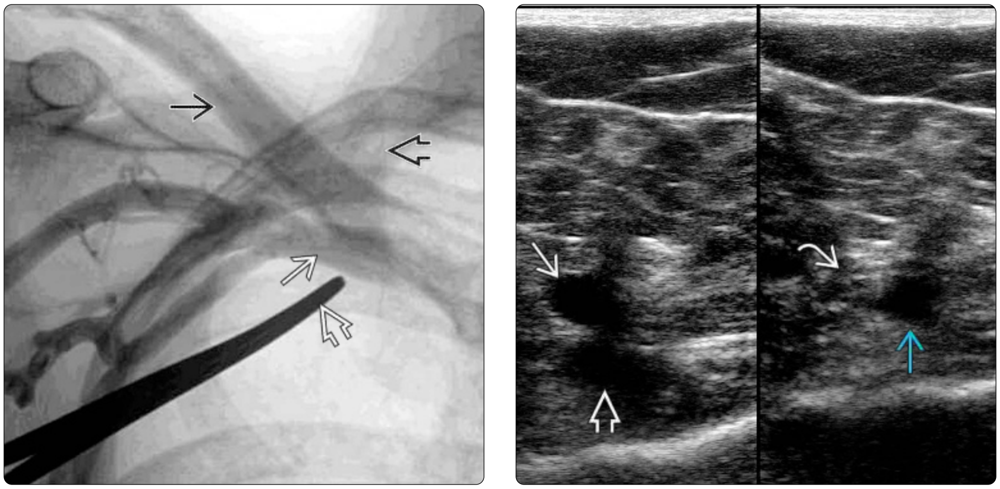
Subclavian Vein Access (Axial CECT)



Subclavian Vein Access (Sagittal CECT)



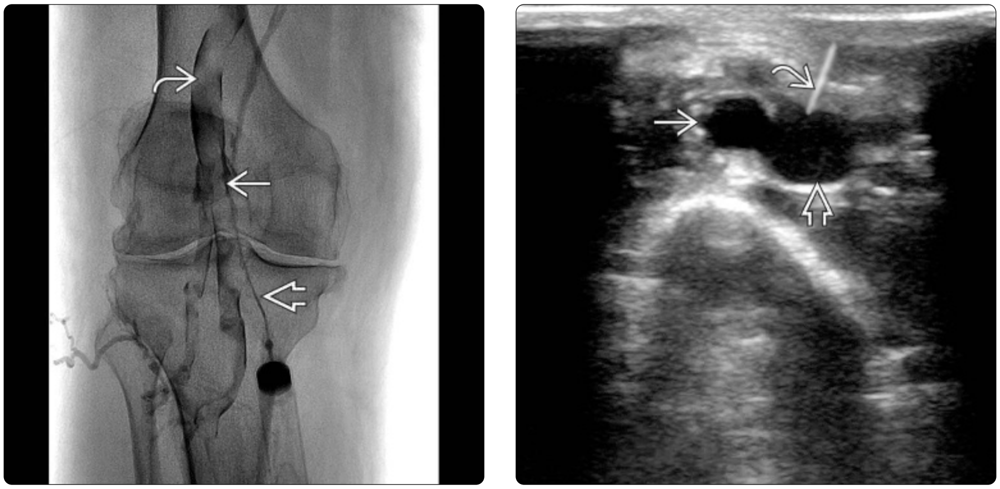
(Left) *Axial CECT through the upper chest shows the subclavian vein* ➡ *coursing between the clavicle* ➡ *and the first rib* ⇨*. The subclavian artery* ⇨ *lies superior and posterior to the vein.* **(Right)** *Sagittal CECT through the junction of the medial and middle clavicle demonstrates the subclavian vein* ➡ *anterior and inferior to the subclavian artery* ⇨*. This is optimal position for the subclavian vein access as underlying 1st rib* ⇨ *reduces chances of pneumothorax.*



Subclavian Vein Access (Venographic Guidance)

Popliteal Vein Access (Axial US With and Without Compression)

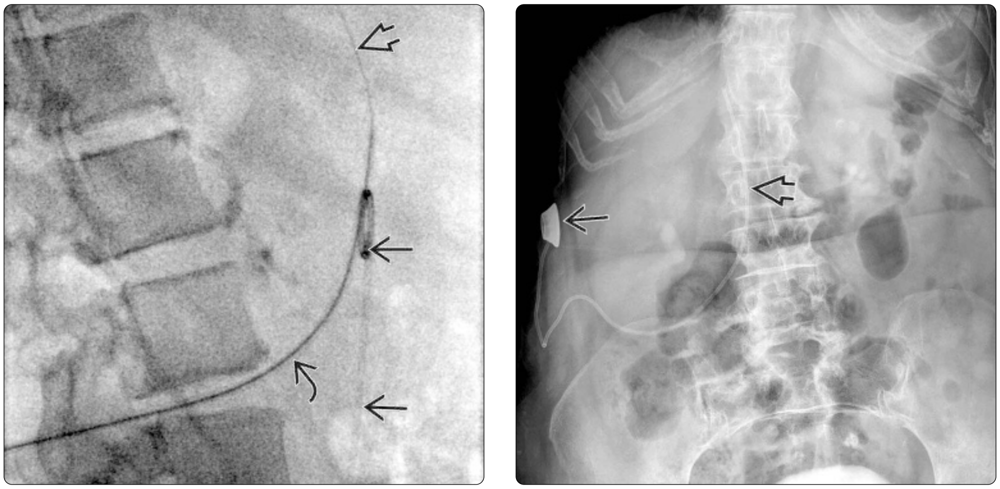
(Left) *Venography-guided access shows a hemostat tip ➡ positioned over the subclavian vein ➡ as it crosses beneath the clavicle ⇨ and overlies the 1st rib ⇨. If the vein is punctured at this point, the underlying rib will prevent the needle from entering the lung and causing a pneumothorax.* **(Right)** *Grayscale US of the left popliteal fossa demonstrates popliteal vein ➡ posterior to the popliteal artery ➡. Right side of the image shows that the vein ➡ is compressible while the artery ⇨ is not.*



Popliteal Vein Access (Acute DVT)

Brachial Vein Access (Axial US)

(Left) *Intraoperative fluoroscopic image shows the popliteal vein ➡ catheterized with a microaccess sheath ➡. Contrast injected through the microsheath outlines numerous filling defects ➡ in the popliteal and femoral veins, consistent with acute DVT.* **(Right)** *Axial US shows the brachial artery ➡ adjacent to the larger brachial vein ➡. The needle tip ➡ can be seen slightly indenting the anterior vein wall. The artery should be pulsatile and the vein compressible.*

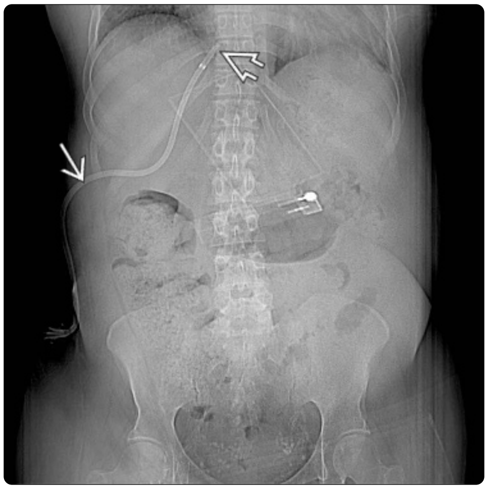


Translumbar IVC Access (Fluoroscopic Imaging)

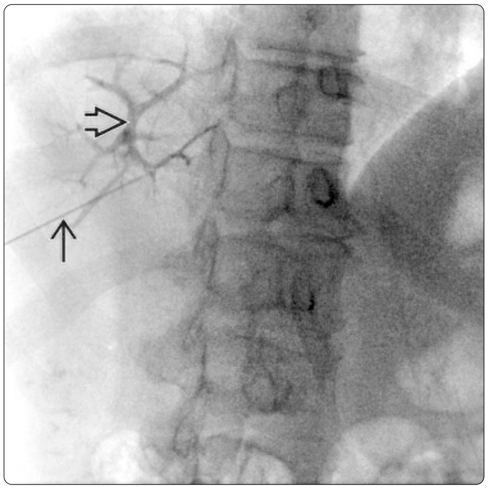
Translumbar IVC Access (Port Placement)

(Left) *A pigtail catheter ⇨ has been positioned within the IVC from a femoral approach to serve as a target for the translumbar needle. Following percutaneous translumbar IVC access with a trocar needle, a guidewire ⇨ is introduced to the IVC, directed cephalad, and a sheath ⇨ is placed.* **(Right)** *Following translumbar port placement, a radiograph shows the port ⇨ overlying a posterolateral rib, and the catheter ⇨ coursing into the IVC, where the tip is positioned above the renal veins in the upper IVC.*

Transhepatic IVC Access

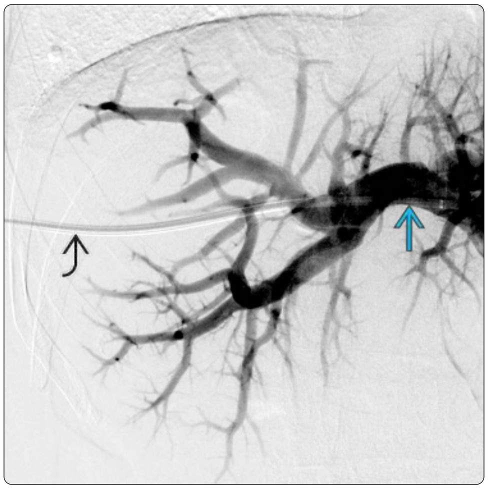


Transhepatic Portal Vein Access (Localization of Portal Veins)

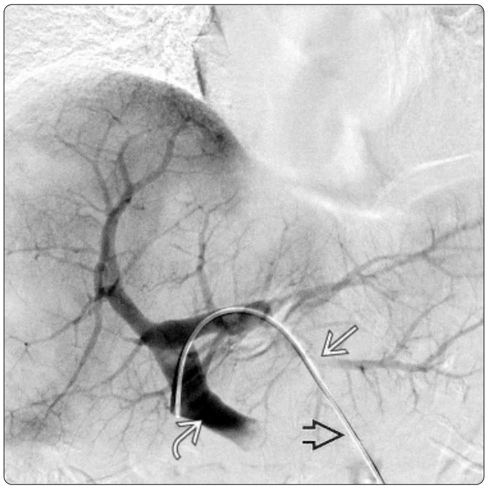


(Left) *CT scout radiograph demonstrates a transhepatic tunneled dialysis catheter → placed via the right hepatic vein. The catheter tip is at the inferior cavoatrial junction ⇨.* **(Right)** *Transhepatic venous access was obtained prior to portal vein embolization. Contrast was injected via a Chiba needle → introduced from a right mid-axillary approach, opacifying right portal vein branches ⇨. A 0.018" guidewire will be introduced through the needle, a transitional dilator placed, and an 0.035" guidewire advanced.*

Transhepatic Portal Vein Access (Access Upsizing)

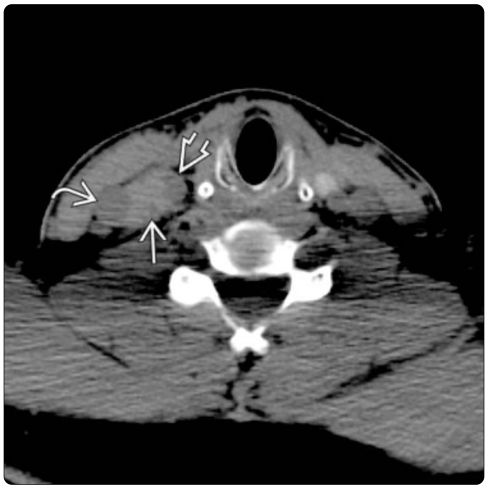


Transhepatic Portal Vein Access (Left Sided)

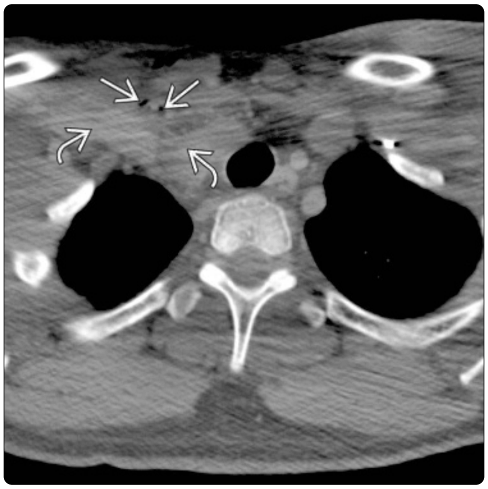


(Left) *Insertion of a sheath ↪ over the 0.035" guidewire, and subsequent central positioning of the sheath in the right portal vein →, allowed catheter introduction and DSA portal venography.* **(Right)** *In an alternate portal vein embolization, a peripheral branch of the left portal vein → was catheterized. The catheter ⇨ was advanced into the main portal vein ↪, and digital subtraction portal venography was performed. Peripheral access reduces the risk of major bleed if hepatic arteries are inadvertently injured during access.*

Jugular Vein Access Complication



Jugular Vein Access Complication



(Left) *Axial NECT obtained after an unsuccessful attempt at blind jugular vein access shows a high-density area → between the right internal jugular vein ↪ and common carotid artery ⇨. Discoloration and swelling were present on physical examination. The findings are consistent with a hematoma, which could be related to puncture of either the jugular vein or the carotid artery.* **(Right)** *Axial CECT at a lower level shows more diffuse hematoma ↪ and soft tissue air → related to the attempted puncture.*

Peripherally Inserted Central Catheters

KEY FACTS

TERMINOLOGY

- Peripherally inserted central catheter (PICC)
  - Approved for inpatient and outpatient access
  - Provides short- and medium-term venous access

PREPROCEDURE

- Various PICC diameters, lengths, configurations
  - Power PICC allows power injection of IV contrast
  - Single-, double-, or triple-lumen catheters

PROCEDURE

- Basilic vein preferred for PICCs, followed by brachial vein; cephalic vein prone to venospasm/thrombosis
- US or venography for image guidance
- Prefer single wall puncture if possible
- Guidewire introduced into vein using fluoroscopy
- Peel-away sheath introduced over guidewire
- Distance to cavoatrial junction marked with wire
- PICC cut to length & inserted through sheath
- PICC secured externally and dressing applied
- Lumina aspirated and then flushed
- Obtain fluoroscopic spot image/chest radiograph after PICC placement/repositioning/exchange
  - Documents tip position at cavoatrial junction

POST PROCEDURE

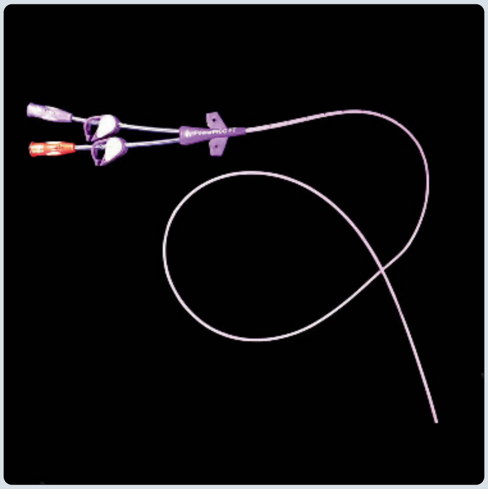
- Frequently flush PICC to prevent luminal occlusion
- Remove promptly when no longer indicated

OUTCOMES

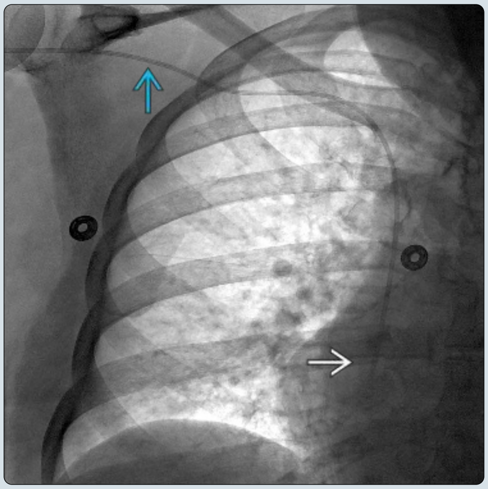
- Most significant complications
  - Infection
  - Malpositioned tip
  - Cardiac arrhythmia
  - Arterial puncture
- Technical success rate: > 95%

(Left) *Photograph shows the typical double-lumen, CT-injectable PICC before it is cut to the appropriate length.* **(Right)** *Fluoroscopic spot radiograph of the right chest shows the catheter ⇨ entering central veins from the right upper extremity. The PICC tip ➡ should be positioned at the cavoatrial junction. Target the inferior 1/2 of the SVC through superior 1/2 of the right atrium. The tip may change location significantly with various patient positions.*

Double-Lumen PICC

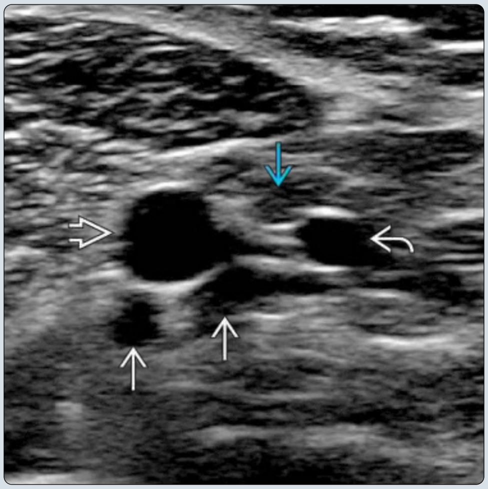


Right Arm PICC

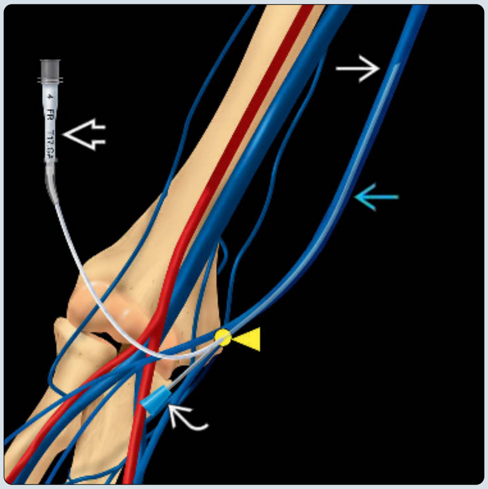


(Left) *Axial US of the midarm demonstrates paired brachial veins ➡ adjacent to the brachial artery ➡. In this patient, the basilic vein ↶ lies in relative proximity to the brachial vessels. Median nerve ⇨ should be avoided when attempting brachial venipuncture.* **(Right)** *Graphic highlights a potential access site (yellow arrowhead) for a needle ↶ and subsequent midline catheter ➡ entering the basilic vein ⇨ near the median antecubital vein. Note the short tip ➡ of the midline catheter.*

PICC Placement



Basilic Vein Midline Catheter Placement



Peripherally Inserted Central Catheters

TERMINOLOGY

Synonyms

- PIC line

Definitions

- **Peripherally inserted central catheter (PICC)**: Small-bore catheter used to provide short- and medium-term venous access
  - Most common central venous catheter (> 1 million catheters placed in USA alone)
  - Approved for both inpatient and outpatient settings

PREPROCEDURE

Indications

- Venous access requiring catheter tip location in central vein, such as superior vena cava (SVC)
  - Infusion therapies with hypertonic solutions, medications that may irritate venous endothelium
    - Antibiotics
    - Chemotherapy
    - Cytotoxins
  - Vasopressors
  - Inotropes in heart failure patients
  - Total parenteral nutrition
  - Provide access for aspiration of blood products (lab work), for administering radiographic contrast
  - Bacteremia, sepsis, or coagulopathy preventing more permanent access

Contraindications

- Central or peripheral venous occlusion/deep venous thrombosis/phlebitis
- No accessible veins in upper extremities
- Hemodialysis patients, renal transplant recipients, individuals with marginal renal function who may require future hemodialysis access
  - Repeated PICC insertions or prolonged catheter presence may cause upper extremity venous thrombosis; may render veins unsuitable for creation of hemodialysis access (e.g., arteriovenous fistula)
  - Consider small-bore tunneled central venous catheter instead
- Controversial in younger patients requiring frequent venous access (e.g., cystic fibrosis, short-gut syndrome)
  - Repeated PICC insertions may cause venous thrombosis, lack of access, chronic arm swelling
  - Consider small-bore tunneled central venous catheter or subcutaneous port insertion

Preprocedure Imaging

- Review any pertinent prior imaging study
- Perform preprocedure US evaluation of planned access vein to confirm anatomy/patency

Getting Started

- Things to check
  - Clinical history/indication
    - Planned duration of treatment
    - Type of infusion/pharmaceutical to be administered
    - Number of lumina needed
  - Coagulopathy: Consensus guidelines recommend correcting INR > 2.0; platelets < 50,000/μL
  - Current medications
    - Warfarin: Goal to achieve INR < 2.0
    - Clopidogrel: Withhold 5 days prior to procedure
    - Aspirin: Do not withhold
    - Low molecular weight heparin (therapeutic dose): Withhold same-day dose
  - Allergies
  - Laboratory results
    - Review coagulation panel, BMP, CBC
  - Physical examination
    - Evaluate access site for irritation/infection
    - Evaluate for prior access
  - Written informed procedural consent
- Medications
  - 1% lidocaine or xylocaine for local anesthesia
  - Heparinized saline (100 IU/mL)
- Equipment list
  - Fluoroscopy equipment
  - US equipment
    - 5- to 8-MHz probe, sterile probe cover, and gel
  - Iodinated radiographic contrast if venography planned
  - Elements for maximum sterile barrier technique
    - Sterile gown and gloves, cap, mask, eyewear
    - Preparatory solution for cutaneous antisepsis
      - 2% chlorhexidine
      - Povidone-iodine and 70% alcohol
    - Sterile barrier drape
  - 10-mL syringe with 25-g needle for local anesthesia
  - Tourniquet (optional)
  - Microaccess set
    - 21-g access needle
    - 0.018" guidewire
    - Peel-away sheath (inner dilator 0.018" lumen, outer sheath lumen compatible with PICC size)
  - Scalpel (#11 blade)
  - Catheter
    - Various diameters, lengths, configurations available
      - Single, dual, or triple lumen
      - "Power PICC" designed for administration of intravenous radiographic contrast using injector
  - Mechanism for externally securing PICC
    - StatLock (Bard; Covington, GA)
    - 3-0 nonabsorbable suture

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Patient supine, arm abducted, palm up
  - Tourniquet can be placed above biceps brachii to distend veins
  - Point of venous access typically above elbow
    - Highly variable anatomy
    - Basilic vein
      - Most frequently used
    - Brachial vein
      - Often duplicated
      - Close proximity to brachial artery and median nerve

  - May require lateral wall venipuncture to avoid artery and nerve injury
- Cephalic vein
  - Smaller vein; prone to venospasm
  - Cephalic arch may be difficult to navigate
  - Highest incidence of catheter-associated thrombosis
- Antecubital vein
  - Uncommonly used

Procedure Steps

- **General**
  - Determine which arm appropriate for PICC placement
    - Most patients prefer nondominant arm
    - May use contralateral arm if prior axillary lymph node dissection; chronic arm swelling
  - Cleanse skin with preparatory solution from upper biceps level to below antecubital fossa
  - Place tourniquet high in axilla (optional)
  - Place sterile drapes to isolate sterile field
- **US guidance**
  - Place sterile cover on 5- to 8-MHz probe
    - Gel on probe crystal; sterile gel externally to sterile probe cover
  - Scan arm veins to determine appropriate target vein
    - Patent vein easily compressible
    - Artery pulsatile, poorly compressible
    - Caution: Tight tourniquet may result in loss of normal arterial pulsation
  - Administer local anesthetic sparingly to skin over target vein
    - Too much local anesthetic may compress or obscure visualization of vein
    - Administer more after vein accessed
  - Obtain target vein access with micropuncture needle
  - Introduce guidewire through needle into vein lumen
    - Should not encounter resistance to wire passage
      - Microwire looping or balling may indicate extravascular location
    - Fluoroscopically monitor guidewire insertion
  - Release tourniquet
  - Make skin nick with #11 scalpel
  - Place peel-away sheath over 0.018" guidewire
    - Advance guidewire to cavoatrial junction and measure guidewire length
    - Venography may be performed if difficulty advancing guidewire centrally
      - Confirms anatomy
      - Evaluates for peripheral or central stenosis/occlusion
  - Cut catheter to appropriate length
    - Measure guidewire from skin to cavoatrial junction to determine length
    - Account for external part of peel-away sheath when measuring wire or PICC will be too long
  - Introduce PICC through peel-away sheath
    - May use wire stiffener inside PICC, do not extend stiffener beyond PICC
    - May introduce catheter over guidewire if challenging to advancing centrally
    - Optimal PICC tip position at cavoatrial junction
  - Aspirate and flush all lumina of PICC
    - Aspiration confirms lumen patency/functionality
    - Heparin solution maintains patency
  - Secure external portion of PICC to skin and apply sterile dressing
    - May suture with 3-0 monofilament
    - Devices for securing without sutures available
- **Venography guidance**
  - Avoid if contrast allergy or renal dysfunction
  - IV angiocatheter or butterfly needle in hand vein
    - Used to inject IV contrast medium for guidance
  - Administer local anesthetic to skin over target vein
  - Tighten tourniquet in axilla
    - Distends veins, prevents contrast egress
  - Inject contrast to opacify veins of upper arm
    - Center fluoroscopy, magnify target vein, collimate
  - Advance needle under fluoroscopy to target vein
    - Pressure of needle tip should visibly indent or "blanch" target vein
    - Gently advance needle tip into vein lumen
      - Try to prevent double wall puncture; if needle exits posterior wall, contrast will extravasate
      - Look for blood or contrast return at needle hub
  - Advance guidewire through needle into vein lumen
    - Fluoroscopically monitor guidewire insertion
  - Remainder of procedure identical to US-guided
- **PICC exchange or repositioning**
  - Excessive PICC length: May simply pull back
  - Malpositioned PICC tip: Reposition or exchange
    - Internal jugular, azygos, contralateral brachiocephalic veins
    - More common when initial PICC too short
  - Exchange required for
    - Catheter malfunction
    - PICC partially pulled out
    - Requirement of additional PICC lumina
  - Thoroughly prep external portion of PICC
  - Introduce 0.018" guidewire through PICC lumen
    - For exchange, completely remove PICC over wire
      - Introduce new peel-away sheath
      - Place new PICC through sheath
    - For repositioning, use wire to redirect PICC position
      - May require partially withdrawing PICC, then advancing wire and PICC into desired location
      - May require inserting longer PICC if tip malpositioned because initial length too short

Findings and Reporting

- Obtain fluoroscopic spot image or chest radiograph following PICC placement, repositioning, or exchange
  - Documents tip position at cavoatrial junction
- Include in procedure report
  - Location of catheter tip, catheter length
  - Documentation of aspirating and flushing lumina

Alternative Procedures/Therapies

- Bedside PICC placement
  - US guidance for access; no fluoroscopic imaging
    - PICC length estimated prior to insertion by externally measuring catheter length from insertion site to chest

        - ☐ Postplacement chest radiograph confirms location
    - – PICC tip confirmation systems available
        - ☐ Sherlock 3CG Tip Confirmation System (Bard Access Systems, Inc, Salt Lake City, UT) magnetically tracks PICC tip and compares with ECG waveform to confirm proper PICC tip location
        - ☐ Need for postplacement CXR questionable
- Midline
    - ○ Peripherally inserted catheter with tip resting at or peripheral to axillary line (typically 20 cm in length)
    - ○ Placed via basilic, cephalic, or median antecubital vein
    - ○ Dwell times typically up to 6 weeks

POST PROCEDURE

Things To Avoid

- Excessive manipulations at venipuncture site/multiple access attempts at the same site; May lead to vasospasm or hematoma with resultant vein occlusion
- Reinsertion of pulled-out catheter
    - ○ May result in catheter-associated infection
- Positioning of catheter too deep in right atrium
    - ○ Arrhythmia
- Intraarterial access: If possible, remove PICC
- Brachial artery or median nerve injury
- Air embolism

Things to Do

- Obtain completion chest x-ray/fluoroscopic image
    - ○ Document catheter position
    - ○ If concern for azygos tip position, obtain lateral view
- Watch access site for bleeding/hematoma
- Flush PICC lumen/lumina after medication administration or 2-3x weekly between uses to prevent occlusion

OUTCOMES

Problems

- If guidewire &/or PICC will not advance centrally
    - ○ May require contrast venogram
        - – Evaluate for venous stenosis/occlusion
            - ☐ Treat stenosis with angioplasty, advance PICC
    - ○ Leave PICC tip peripheral to axillary line (midline) if clinically acceptable

Complications

- Immediate/periprocedural complication(s)
    - ○ Arterial puncture
    - ○ Bleeding or hematoma
        - – < 1% risk of significant hemorrhage
    - ○ Cardiac arrhythmia
        - – May occur during wire or catheter introduction
    - ○ Malpositioned catheter tip
    - ○ Nerve injury
        - – More common if brachial venous access attempted
    - ○ Air embolus
- Delayed complication(s)
    - ○ Venous thrombosis
        - – Thrombosis rates by site of access
            - ☐ Brachial (10%)
            - ☐ Basilic (14%)
            - ☐ Cephalic (57%)
    - ○ Phlebitis (4%)
    - ○ Venous stenosis
    - ○ Cardiac arrhythmia
        - – Malpositioned tip/excessive catheter length
    - ○ Infection
        - – Most common bacteria are enterococci and Methicillin-resistant *Staphylococcus aureus*
        - – Infection rate increases proportionally to duration of catheter presence and number of lumina
        - – Patterns of infection: Catheter colonization; catheter-related bloodstream infection; exit-site infections
    - ○ PICC malfunction: Inability to flush/aspirate
        - – Fibrin or thrombus occluding end hole
        - – Catheter kink
        - – Catheter fracture
            - ☐ Most likely to occur during PICC removal
        - – Catheter malposition or migration
            - ☐ Catheter tip may migrate into contralateral brachiocephalic, internal jugular, or azygos veins
        - – Catheter tip abutting or adherent to vessel wall

Management of PICC-Specific Complications

- Venous thrombosis
    - ○ Systemic anticoagulation
    - ○ Remove/resite catheter if clinically worsening
- Infection
    - ○ Determine source
        - – Direct catheter culture
        - – Simultaneous blood cultures from catheter and peripheral site
    - ○ Catheter should be removed/resited
    - ○ Antibacterial treatment
        - – Positive cultures
        - – Empiric treatment if clinical evidence of sepsis
- PICC malfunction
    - ○ Evaluate radiographically (positioning, physical integrity)
    - ○ Malpositioned catheters
        - – May attempt to reposition under fluoroscopy
        - – Exchange/reposition if unsuccessful
    - ○ Fibrin sheath or thrombosis
        - – Fill catheter lumina with 2 mg of alteplase with dwell time of 60 minutes
        - – Aspirate vigorously
        - – Repeat 1 or 2 times
        - – Alternatively, infuse 2 mg of alteplase in 50 mL of normal saline at rate of 17 mL/hr

Expected Outcomes

- Technical success rate: > 95%

SELECTED REFERENCES

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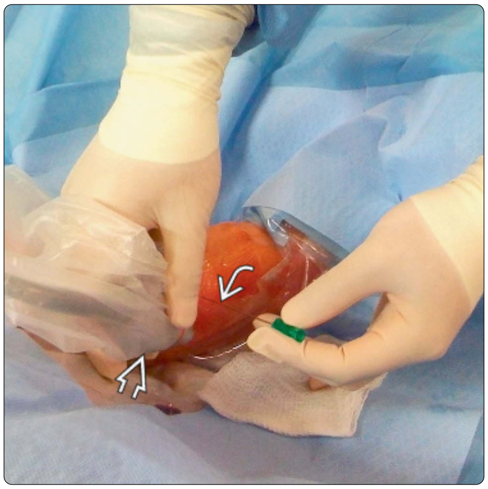
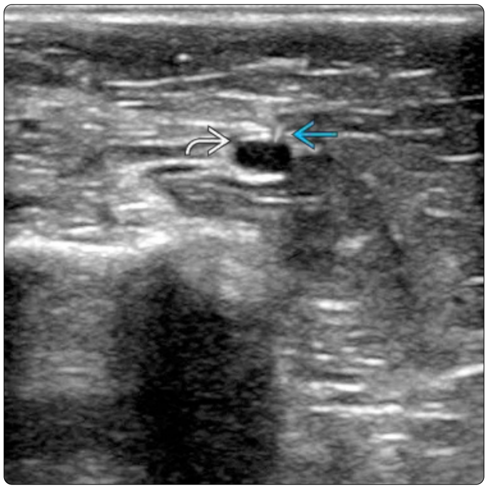
2. Braswell LE: Peripherally inserted central catheter placement in infants and children. Tech Vasc Interv Radiol. 14(4):204-11, 2011
3. Butler PJ et al: Previous PICC placement may be associated with catheter-related infections in hemodialysis patients. Cardiovasc Intervent Radiol. 34(1):120-3, 2011
4. Crowley JJ: Vascular access. Tech Vasc Interv Radiol. 6(4):176-81, 2003

(Left) *Intraoperative photograph shows a sterilely covered US probe* ➡ *being used to identify a suitable vein. A micropuncture needle* ➡ *is introduced into the target vein under US guidance.* **(Right)** *Axial US during PICC placement shows the echogenic needle tip* ⇨ *indenting the anterior wall* ➡ *of the basilic vein. The needle is advanced into the lumen and the hub is observed for blood return, confirming an intraluminal needle tip position.*

US-Guided PICC Placement, Step-by-Step (US Guidance)

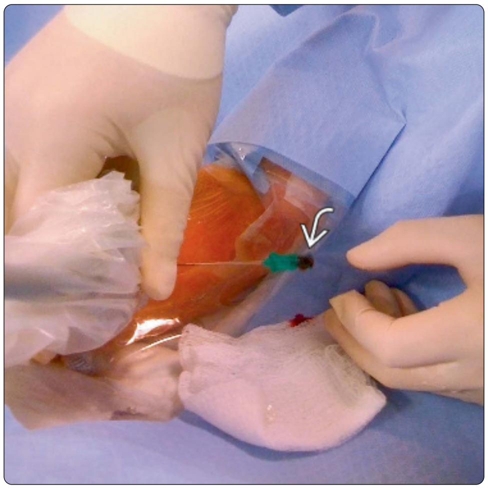


US-Guided PICC Placement, Step-by-Step (US Guidance)

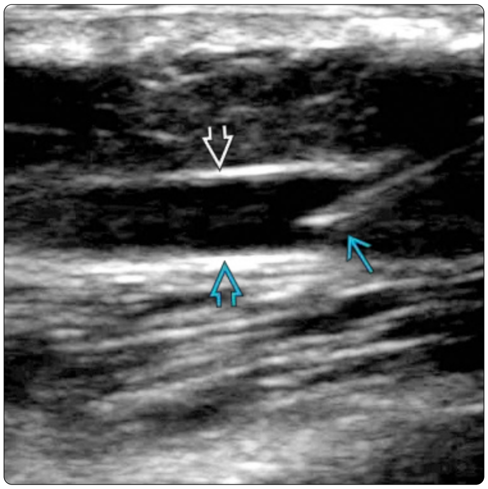


(Left) *Intraoperative photograph shows blood return at the needle hub* ➡*, confirming intraluminal access. Handle the needle delicately at this time to prevent loss of access. Actions as minimal as removing the US probe can result in dislodgement of the needle tip.* **(Right)** *Sagittal US confirms that the needle tip* ⇨ *has been successfully advanced to an intraluminal position. The anterior* ➡ *and posterior* ⇨ *walls of the vein and the echolucent venous lumen are well visualized.*

US-Guided PICC Placement, Step-by-Step (Venipuncture)

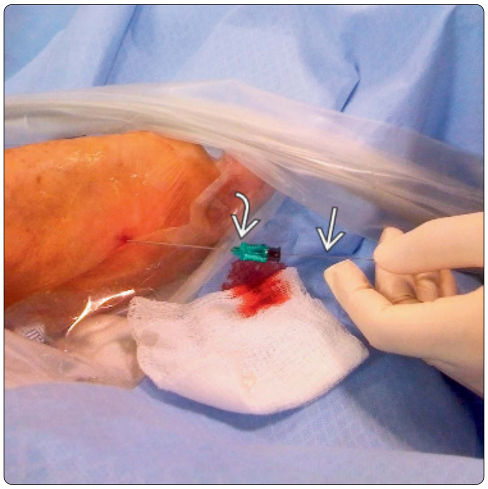


US-Guided PICC Placement, Step-by-Step (Venipuncture)

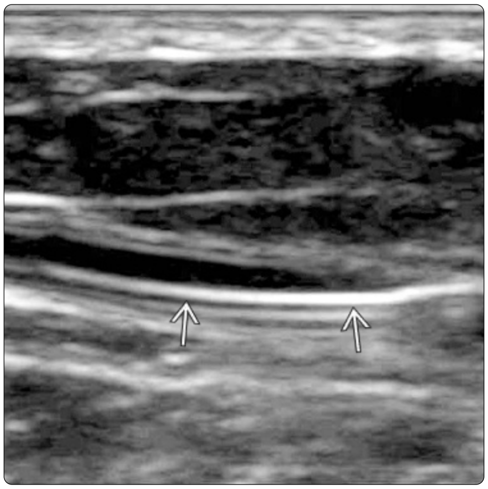


(Left) *A microwire* ➡ *is introduced though the microaccess needle* ➡ *into the lumen of the target vein. During microwire insertion, no resistance should be encountered to wire passage. Wire advancement can be aided by rotating the needle bevel up (away from skin), slightly spinning the wire, and utilizing a Nitinol (e.g., Nitrex) microwire.* **(Right)** *Sagittal US shows that the microwire* ➡ *has been introduced intraluminally via the needle. The remainder of the PICC placement is performed using fluoroscopy.*

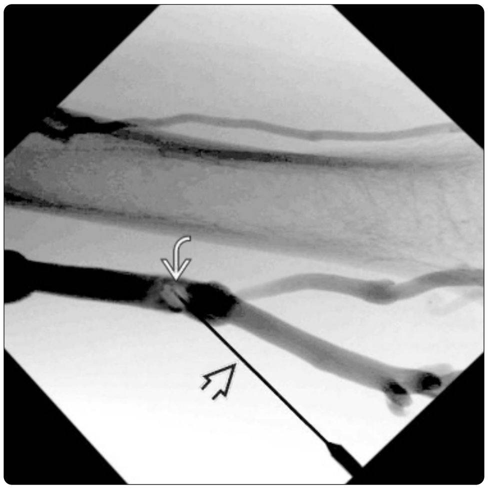
US-Guided PICC Placement, Step-by-Step (Microwire Insertion)



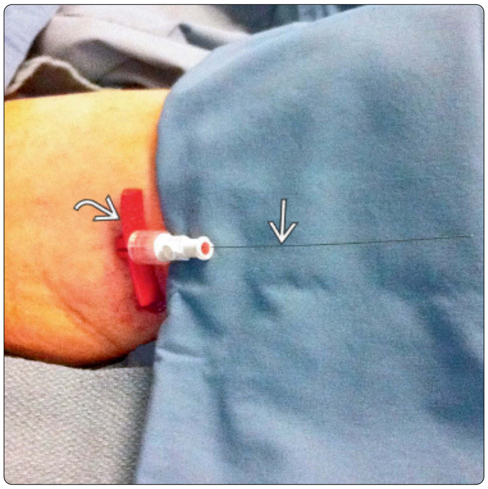
US-Guided PICC Placement, Step-by-Step (Microwire Insertion)



Venography-Guided Venous Access

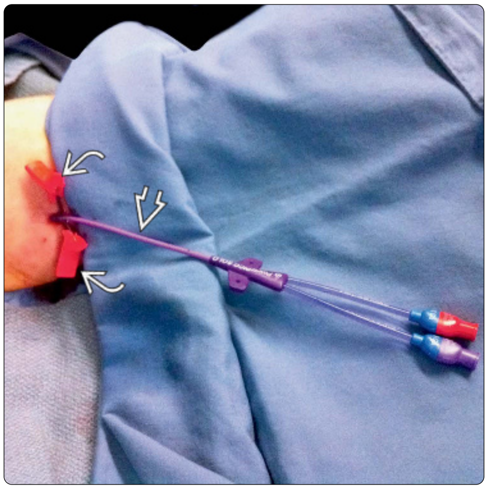


PICC Placement, Step-by-Step (Peel-Away Sheath Introduction)

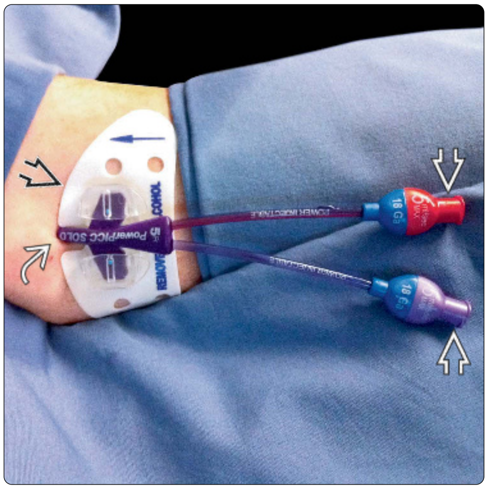


(Left) *As an alternate to US guidance, fluoroscopic venography-guided venous access may be performed. The needle ⇨ against the vessel wall causes the intraluminal contrast to "blanch" ↪ prior to needle entering lumen.* **(Right)** *After fluoroscopically confirming microwire tip location, a peel-away sheath ↪ is introduced over the microwire →. The length of the wire from entry to the cavoatrial junction is marked (with hemostats or a bend of the wire). The wire is removed and the PICC cut to this length.*

PICC Placement, Step-by-Step (PICC Insertion)

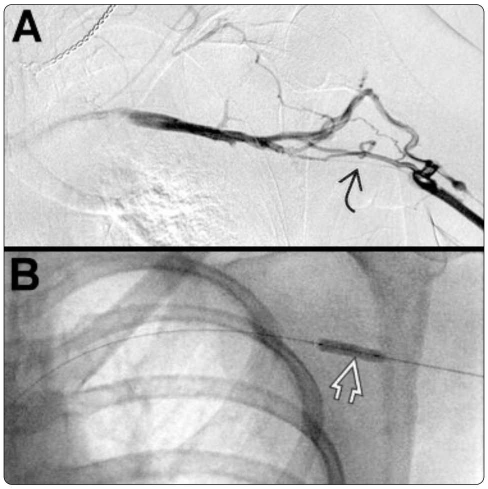


PICC Placement, Step-by-Step (PICC Fixation)

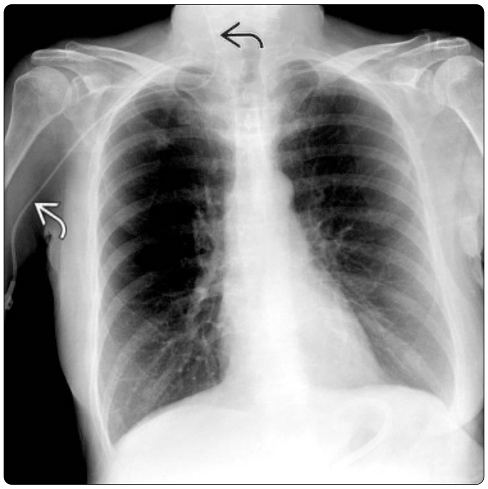


(Left) *The PICC is advanced through the peel-away sheath before the sheath is split ↪. The PICC diameter widens ➡ to seal the venous access, and so it will not advance entirely until the sheath is removed. Advance a microwire or stiffener through the PICC as needed to achieve tip position at the cavoatrial junction.* **(Right)** *The flared portion of the PICC ↪ is advanced to the skin. The PICC is then secured either with sutures or a fixation device, such as the StatLock ⇨. Aspirate and flush through lumina ➡ to ensure proper function.*

PICC-Associated Venous Stenosis



Malpositioned PICC



(Left) *(A) Venogram shows a severely stenotic left basilic vein ⤷ in an asymptomatic patient with a history of multiple PICC lines. The catheter would not pass the stenosis. (B) Venous angioplasty ➡ was performed, allowing successful PICC insertion.* **(Right)** *A radiograph in a different patient shows the tip ⤷ of a right arm PICC ↪ coursing into the neck. This malpositioned PICC should be exchanged over a guidewire for a new centrally positioned PICC, thus avoiding potential jugular vein thrombosis.*

Nontunneled Catheters

KEY FACTS

TERMINOLOGY

- **Nontunneled catheter**: Short-term central venous catheter placed percutaneously into central veins
    - Typical dwell time of days to weeks

PREPROCEDURE

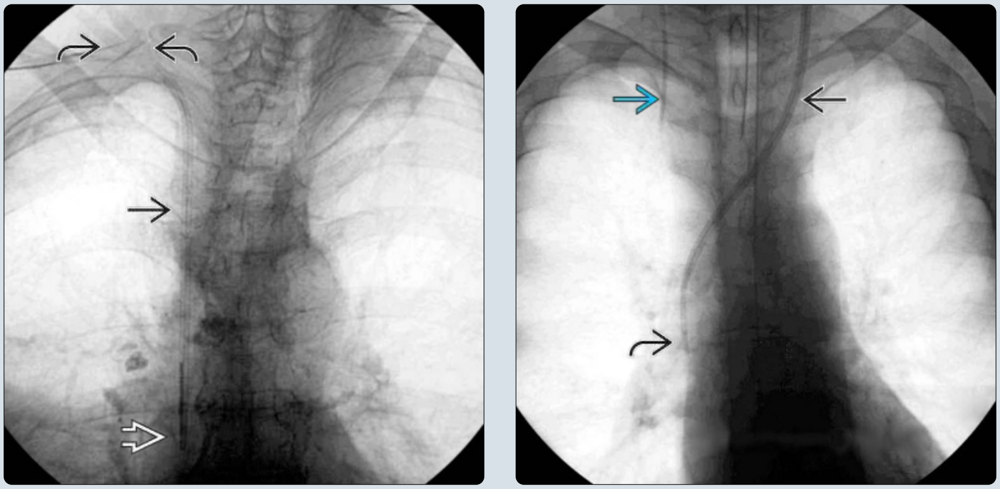
- Indications
    - Short-term central venous access
    - Temporizing measure until tunneled catheter can be placed; can be used for same purposes
    - Hemodynamic monitoring

PROCEDURE

- **Choice of access**
    - Right internal jugular vein access preferred
    - Subclavian vein least preferred upper access route
    - Femoral vein access has highest rate of thrombosis/infection
- **Procedure steps**
    - Obtain venous access using US guidance
    - Advance guidewire into central vein
    - Dilate skin tract for dialysis/pheresis catheters
    - Introduce catheter over guidewire
        - Use peel-away sheath over guidewire for some catheter designs
    - Position catheter tip at cavoatrial junction
    - Aspirate/flush catheter lumina; apply dressing
    - Obtain completion chest radiograph

OUTCOMES

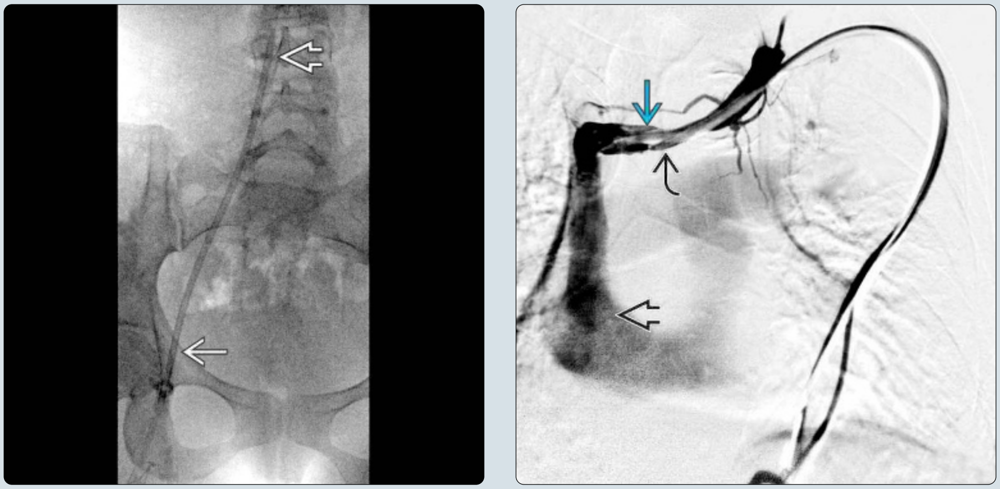
- > 99% success rate for image-guided placement
- Complications
    - Pneumothorax (1%)
    - Nontunneled central venous catheters have highest infection rate of any type of venous access
    - Frequent catheter-induced venous thrombosis



Right IJV Hemodialysis Catheter

Left IJV Hemodialysis Catheter

(Left) *A nontunneled hemodialysis catheter ⇨ enters the right internal jugular vein (IJV) with the tip ➩ at the cavoatrial junction. Catheter hubs ↪ are visible near entry site. The right IJV is the preferred venous access for both nontunneled and tunneled catheters.* **(Right)** *Chest radiograph shows a left IJV dual-lumen non-tunneled hemodialysis catheter → with the tip ↪ positioned in the superior vena cava (SVC). A shorter right IJV single-lumen nontunneled central venous catheter → is also seen.*



Right Common Femoral Hemodialysis Catheter

Suboptimal Left Subclavian Hemodialysis Catheter

(Left) *A nontunneled hemodialysis catheter ➡ enters the right common femoral vein and terminates with the tip ➩ in the inferior vena cava (IVC). Femoral access may be used if no upper access route is available.* **(Right)** *DSA venogram shows the non-tunneled hemodialysis catheter poorly positioned. The catheter tip is located in the left brachiocephalic vein ↪, rather than the preferred location within the larger right atrium ⇨, where catheter tip thrombosis → is less likely to occur.*

TERMINOLOGY

Synonyms

- Temporary central venous catheter
- Temporary dialysis catheter
- Central venous catheter

Definitions

- **Nontunneled catheter**: Short-term central venous catheter placed percutaneously into central veins of chest/abdomen
  - Catheter of choice in management of acute medical conditions
  - Typical dwell time of days to weeks
  - Not appropriate for outpatient setting
- **Types of nontunneled catheters**
  - **End-hole catheter**
    - Most common type
    - Tip may be trimmed to required length
  - **Staggered-tip catheter**
    - Designed to allow simultaneous aspiration/infusion with minimal mixing
      - Typical use is for temporary hemodialysis or plasmapheresis
      - Cannot trim tip
  - **Valve-tip catheter**
    - Valve opens inward for aspiration/outward for infusion
      - Cannot trim tip
      - Adaptor allows external portion of catheter to be trimmed to appropriate length

PREPROCEDURE

Indications

- Short-term central venous access
  - If tunneled catheter contraindicated
    - Infection at insertion site, proven bacteremia
      - Tunneled catheter will become colonized
    - Coagulopathy prevents placement
  - Temporizing measure until tunneled catheter can be placed; can be used for same purposes
    - Infusion therapy
      - Chemotherapy
      - Total parenteral nutrition
      - Caustic medications
    - Withdrawal/replacement therapy
      - Pheresis
      - Stem cell therapy
      - Hemodialysis
  - Hemodynamic monitoring (i.e., pulmonary artery catheter)

Contraindications

- Relative contraindications include
  - Coagulopathy: International normalized ratio (INR) > 2.0; platelets < 50,000/μL
  - Thrombosis or chronic occlusion of target vein
  - Central venous occlusion
- Allergy to material of catheter

Preprocedure Imaging

- Review any pertinent prior imaging study
- Perform preprocedure US evaluation of planned access vein to confirm anatomy/patency

Getting Started

- Things to check
  - Clinical history/indication
    - Planned duration of treatment
    - Number of catheter lumina required
    - Type of treatment or infusion/pharmaceutical to be administered
  - Any prior history of central venous catheters
    - Increased risk of occluded veins with prior catheters, history of dialysis
  - Prior imaging
    - Determine best route of access
    - Evaluate patency of planned access route
  - Current medications
    - Warfarin: Goal to achieve INR < 2.0
    - Clopidogrel: Do not withhold
    - Aspirin: Do not withhold
    - Low molecular weight heparin (therapeutic dose): Ideally withhold same day dose
  - Review allergies
  - Laboratory results (review if available)
    - Platelet count/hematocrit not routinely recommended
    - INR recommended for patients with liver disease or receiving warfarin
  - Physical examination
    - Evaluate access site for irritation/infection
    - Evaluate for prior access
  - Obtain written informed procedural consent
- Medications
  - 1% lidocaine or Xylocaine for local anesthesia
  - Heparinized saline (100 IU/mL)
  - Heparin
- Equipment list
  - Fluoroscopy equipment
    - Guidance for guidewire/catheter introduction
    - Confirmation of catheter tip location
  - US equipment
    - Confirmation of venous patency
    - Guidance during venous access
      - 5- to 8-MHz probe with sterile probe cover
  - Elements for maximum sterile barrier technique
    - Sterile gown and gloves, cap, mask, eyewear
  - Preparatory solution for cutaneous antisepsis
    - 2% chlorhexidine
    - Povidone-iodine and 70% alcohol
  - Sterile barrier drape
  - Access needle (may use micropuncture or 18-g)
    - Microaccess set
      - 21-g access needle
      - 0.018" guidewire
      - Microaccess dilator/sheath combination
    - 0.035" guidewire
      - J-tip or short Amplatz
    - Peel-away sheath compatible with catheter size

    - Scalpel
      - #11 blade
    - Appropriate catheter for clinical indication
      - Catheter type: Central venous catheter, dialysis catheter, pheresis catheter
      - Single, dual, or triple lumen
  - 10-mL syringe with 25-g needle for local anesthetic
  - Mechanism for externally securing catheter
    - StatLock (Bard; Covington, GA)
    - 3-0 nonabsorbable suture

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Preferred access route
    - Internal jugular vein (IJV) access preferred
      - Right preferred over left IJV
      - External jugular veins if IJVs occluded
    - Common femoral vein access
      - Used if no IJV access route available
      - Injury to neck/upper chest
      - High infection rate; avoid when possible
    - Subclavian vein least preferred upper access route
      - Much higher risk of pneumothorax
      - Higher incidence of symptomatic thrombosis/stenosis
- Place patient supine
  - Turn head away from target IJV

Procedure Steps

- **IJV nontunneled catheter**
  - Obtain IJV access
  - Introduce microwire & microsheath
  - Advance 0.035" guidewire into inferior vena cava (IVC) under fluoroscopic guidance
  - Determine appropriate length of catheter required
    - Measure microwire to determine length
    - Account for external part of sheath when measuring wire or catheter will be too long
    - Central venous catheter may need to be cut to desired length
    - Plan to position catheter tip at cavoatrial junction
  - Dilate skin tract for hemodialysis/pheresis catheters
  - Advance central venous catheter (per catheter type)
    - Advance catheter over guidewire under fluoroscopic guidance
    - Alternatively, advance catheter through peel-away sheath
      - Introduce peel-away sheath over guidewire under fluoroscopic guidance
      - Remove guidewire & sheath dilator, introduce catheter through peel-away sheath
  - Confirm catheter tip properly located
  - Aspirate/flush catheter lumina
  - Instill dialysis/pheresis catheter lumina with heparin according to manufacturer's instructions
  - Secure catheter to skin and apply sterile dressing
  - Obtain postplacement fluoroscopic image or chest radiograph
    - Documents catheter course/tip position
    - Excludes pneumothorax, mediastinal widening, catheter tip at unexpected location
- **Subclavian vein nontunneled catheter**
  - Obtain subclavian vein access
  - Introduce guidewire through access needle into subclavian vein
    - Otherwise, same steps as for IJV nontunneled catheter placement
- **Common femoral vein nontunneled catheter**
  - Obtain common femoral vein access
  - After initial guidewire/sheath introduction
    - Advance 0.035" guidewire into IVC
    - Otherwise, same steps as for IJV nontunneled catheter placement
      - Typically longer catheter lengths so tip located centrally in IVC

Alternative Procedures/Therapies

- Radiologic
  - Peripherally inserted central catheter
    - Lower flow rates than central catheters
    - Avoid in renal failure patients; preserve arm veins
      - Arm veins may potentially be needed for future creation of arteriovenous (AV) hemodialysis fistula
  - Tunneled central venous catheter
    - Lower infection rate than nontunneled
    - If longer-term central IV access needed
- Surgical
  - Bedside US-guided or "blind" placement
    - Chest radiograph obtained after placement
      - Confirm catheter tip location
      - Exclude pneumothorax
    - Multiple publications demonstrate substantially fewer complications when US used for access guidance

POST PROCEDURE

Things to Do

- Observe access site for bleeding or hematoma
  - Elevate head of bed after upper venous access if possible
    - Decreases venous pressure at access site
    - Decreases bleeding/hematoma risk
- After catheter insertion
  - If inserted with fluoroscopic guidance
    - Obtain fluoroscopic spot image
      - Documents catheter course, tip position
  - Bed-side placement: AP upright inspiratory/expiratory chest film
    - Documents catheter course, tip position
    - Excludes pneumothorax after upper venous access

Things to Avoid

- If catheter externally secured with suture
  - Avoid puncturing catheter with suture needle
  - Do not "crimp" catheter with purse-string
- Positioning of catheter tip deep in right atrium
  - May cause arrhythmia
- Air embolism

Management of Nontunneled Catheter-Specific Complications

- Infection
  - Catheter should be removed/resited
  - Determine source
    - Culture catheter tip
    - Simultaneous blood cultures from catheter and peripheral site
  - Antibacterial treatment
- Venous thrombosis
  - Systemic anticoagulation
- Catheter malfunction
  - Evaluate with radiographically for positioning and physical integrity
  - Malpositioned catheters
    - May attempt to reposition under fluoroscopy
    - Exchange/reposition if unsuccessful
  - Fibrin sheath or thrombosis
    - Fill catheter lumens with 2 mg of alteplase with dwell time of 60 min
    - Aspirate vigorously
    - Repeat 1 or 2 times
    - Resite if unsuccessful
    - Alternatively, infuse 2 mg of alteplase in 50 mL of normal saline at rate of 17 mL/hour

OUTCOMES

Complications

- Immediate/periprocedural complication(s)
  - Pneumothorax (1-3%)
  - Air embolism (< 1%)
    - Greater incidence with dialysis catheter placement
  - Arterial puncture (1-3%)
  - Superior vena cava tear/cardiac tamponade (< 1%)
  - Hemorrhage (< 1%)
    - Even in patients with coagulopathy, thrombocytopenia
  - Hemothorax (< 1%)
  - Guidewire or catheter-induced ectopy
- Delayed complication(s)
  - Infection
    - Nontunneled central venous catheters have highest infection rate of any type of venous access
      - Infection rate: 5.3/1,000 catheter days
      - Cause of majority of catheter-related bacteremia/sepsis cases
    - Most common bacteria are enterococci and methicillin-resistant *Staphylococcus aureus*
    - Patterns of infection
      - Catheter colonization
      - Catheter-related bloodstream infection
      - Exit-site infections
    - Point of access influences infection risk
      - Highest infection rate in femoral catheters
  - Venous thrombosis
    - Catheter-induced central venous thrombosis occurs frequently
      - Highest for femoral catheter (~ 20%)
      - Overall risk: 4%
  - Catheter malfunction (10%)
    - Suboptimal infusion/aspiration
      - Catheter malposition
      - Fibrin sheath/thrombus formation in/around catheter tip
      - Seen more often with tunneled catheters because of longer dwell times

Expected Outcomes

- > 99% success rate for image-guided placement
- 5-13% failure rate for blind access
- Catheter longevity limited by patency/infection

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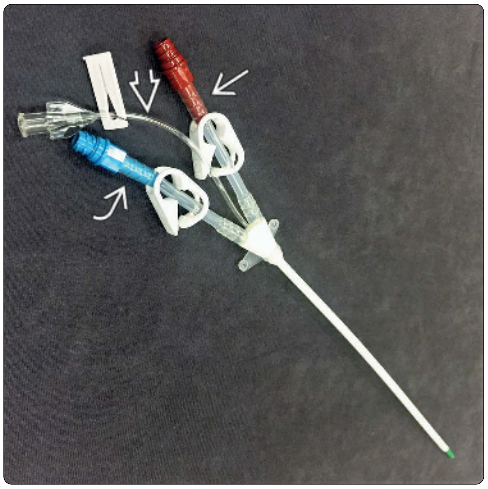
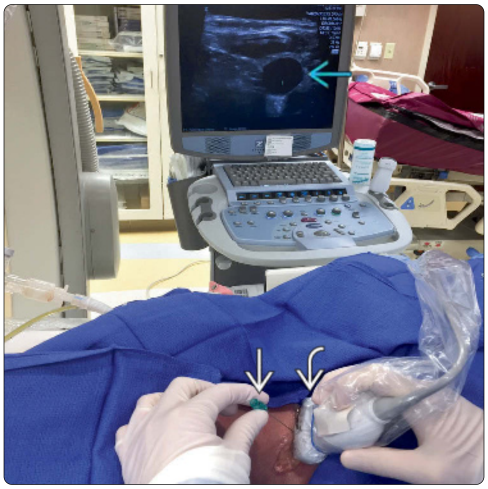
Nontunneled Hemodialysis Catheter

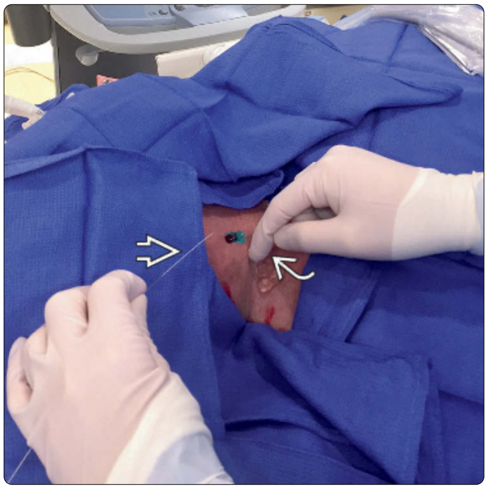


Step-by-Step: Nontunneled Catheter Placement (US-Guided Right IJV Access)

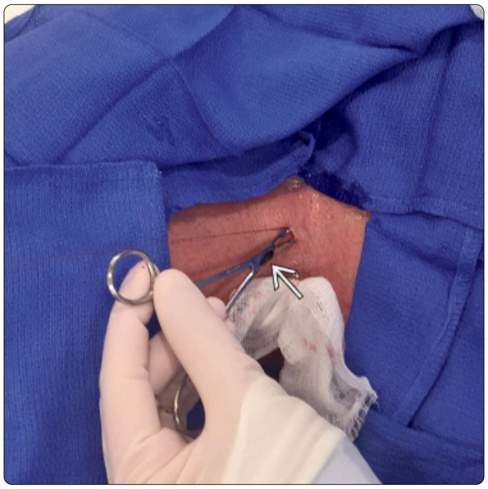


(Left) *This nontunneled hemodialysis catheter for short-term venous access has 2 hubs, which allow blood withdrawal* ➔ *and return* ↪ *during dialysis. In this example, there is a 3rd lumen* ⇨ *available for the administration of medications.* **(Right)** *Proper positioning is key to gaining venous access. The patient, US unit, and table height should be comfortably located. The vessel* → *should be centered on the screen and the needle* ➔ *centered on the probe* ↪.

Step-by-Step: Nontunneled Catheter Placement (Microwire Advancement)

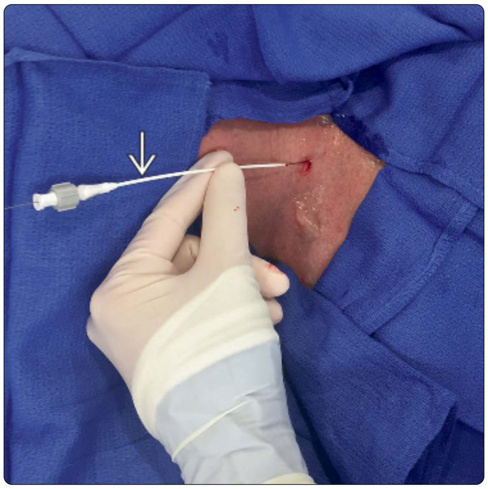


Step-by-Step: Nontunneled Catheter Placement (Dermatotomy Enlargement)

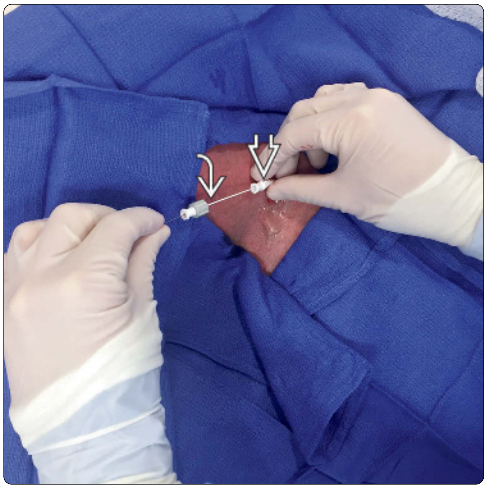


(Left) *Following return of dark blood, the needle can be gently tilted* ↪ *to align with the course of the vein as a microwire* ⇨ *is advanced. If the wire does not advance easily, rotate the wire, alter the needle angle, use fluoroscopy, or reaccess. Do not retract the needle with the wire inserted.* **(Right)** *Some proceduralists make a skin nick prior to needle access, some after. Either way, the skin nick can be enlarged with blunt hemostats* ➔ *rather than a blade, due to elasticity of the skin.*

Step-by-Step: Nontunneled Catheter Placement (Transitional Dilator)

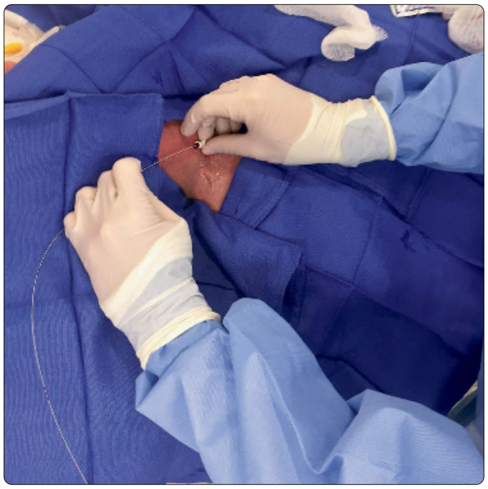


Step-by-Step: Nontunneled Catheter Placement (Microdilator/Wire Removal)

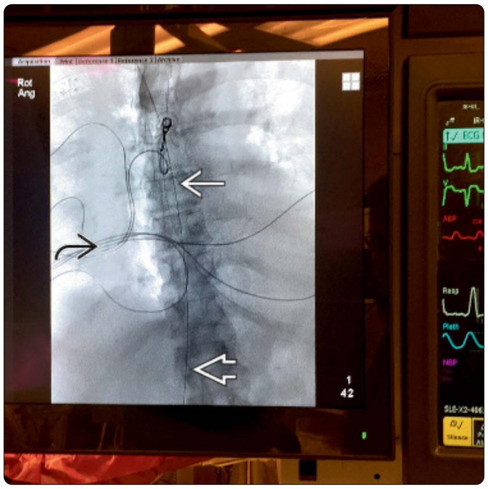


(Left) *If fluoroscopy is available during the procedure, check microwire location. The transitional dilator* ➔ *is then advanced over the microwire.* **(Right)** *Remove the microsheath dilator* ↪ *along with the microwire, and place a digit over the microsheath* ⇨ *to prevent bleeding (typically during patient expiration) or air embolism (during patient inspiration).*

Step-by-Step: Nontunneled Catheter Placement (Guidewire Placement)

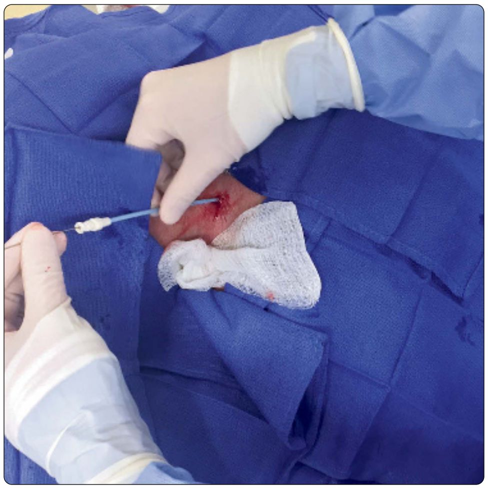


Step-by-Step: Nontunneled Catheter Placement (Guidewire Visualization)

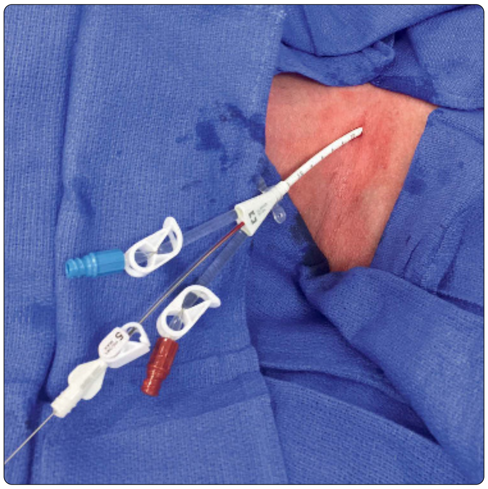


(Left) *A nonhydrophilic guidewire should advance easily through the microdilator into the central veins under fluoroscopic guidance. If fluoroscopy is not available and the wire is not easily passing, do not force the wire. The procedure should be halted and reattempted with imaging guidance.* **(Right)** *Optimize monitors to aid with the procedure, limiting distance and reflections. Reposition or remove cardiac wires ↪ interfering with visualization. Monitor for arrhythmia as the guidewire → advances into the IVC ⇨.*

Step-by-Step: Nontunneled Catheter Placement (Tract Dilation)

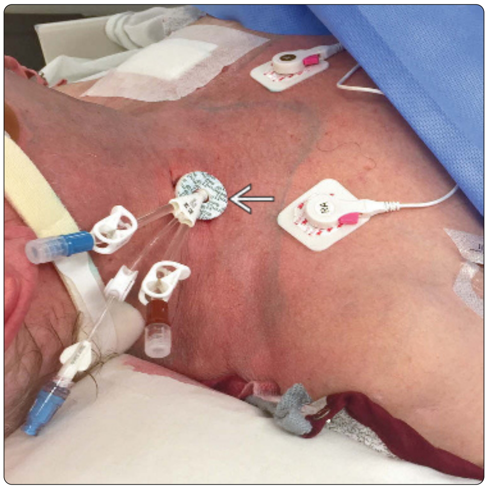


Step-by-Step: Nontunneled Catheter Placement (Catheter Insertion)

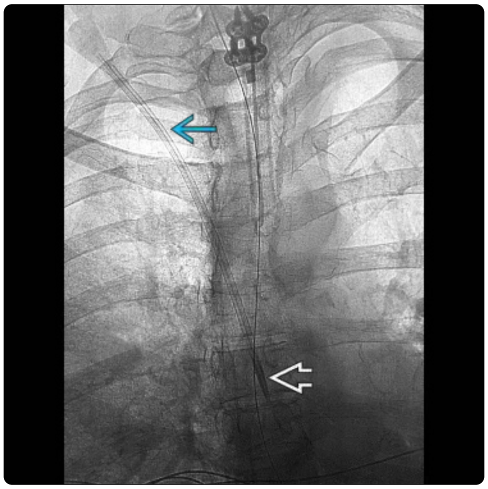


(Left) *The skin tract is dilated over the guidewire. The dilator need be advanced only as deep as the vein, and certainly not further than the known distance of the guidewire. Advancing the dilator past the end of the guidewire can lead to mediastinal perforation and death.* **(Right)** *Some nontunneled catheters are cut to length, others are placed through a peel-away sheath. This catheter advances over the guidewire similarly as would a dilator, but until the catheter is hubbed. Remove the wire and ensure that the catheter functions properly.*

Step-by-Step: Nontunneled Catheter Placement (Final Catheter Position)



Step-by-Step: Nontunneled Catheter Placement (Final Catheter Position)



(Left) *The catheter is then flushed with saline or packed with heparin and secured to the skin with an adhesive device or suture, per hospital protocol. An antimicrobial disc → may be applied. The catheter is then dressed (not shown).* **(Right)** *Fluoroscopic image documents position of the nontunneled catheter → and catheter tip ⇨ in the expected location of the right atrium. Ensure that there is no pneumothorax or mediastinal widening and that the catheter tip is not significantly crossing the midline (i.e., arterial placement).*

Tunneled Catheters

KEY FACTS

TERMINOLOGY

- Definition: Intermediate- or long-term venous catheter introduced through subcutaneous tunnel into central veins of chest or abdomen
  - Tunnel forms natural infection barrier
  - Various tunneled catheters for range of indications

PROCEDURE

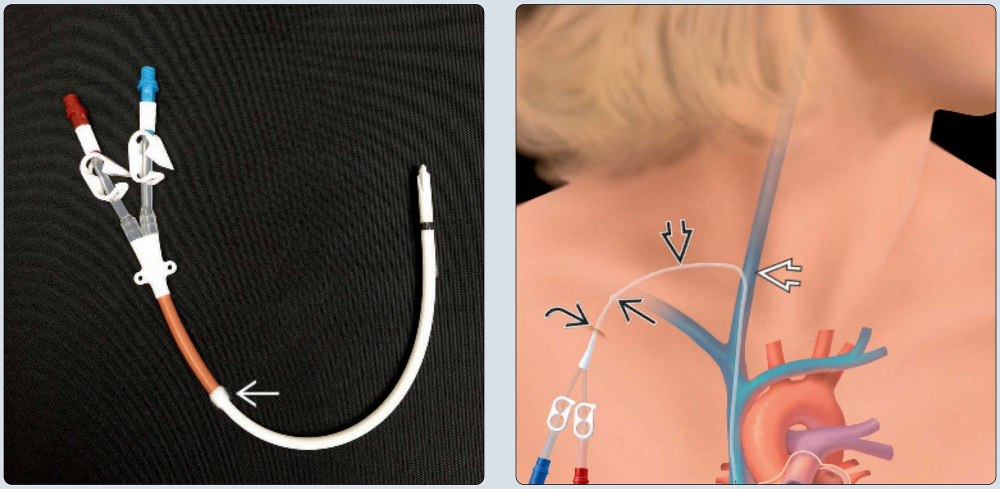
- Internal jugular vein access preferred (right > left)
  - Obtain internal jugular vein access, place dilator
- Create subcutaneous tunnel; course to venotomy
  - Pull catheter through tunnel to venotomy
  - Catheter cuff should be within tunnel
- Replace dilator with peel-away sheath
- Introduce catheter through peel-away sheath
  - Remove sheath, keep catheter in place
- Position catheter tip at mid right atrium

POST PROCEDURE

- Management of infection
  - Transient bacteremia, consider catheter exchange
  - Remove catheter for positive blood cultures/septicemia
- Management of catheter malfunction
  - Exchange/replace catheter

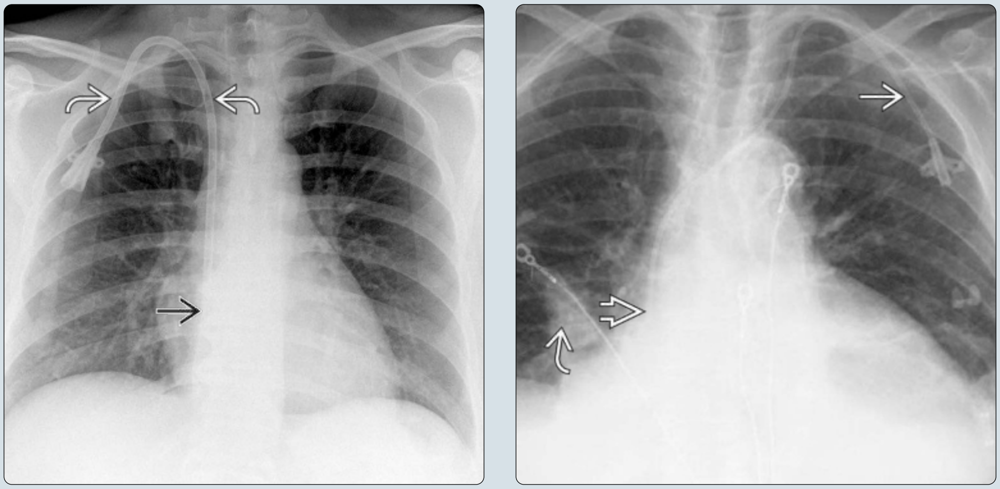
OUTCOMES

- Complications include
  - Massive air embolism (>1%)
  - Bleeding or hematoma (incidence: 0.2%)
  - Infection (incidence: 5-10%; increases over time)
  - Catheter malfunction (incidence: 10-20%)
  - Venous thrombosis (delayed complication)
- Expected outcomes
  - > 95% success rate in tunneled catheter placement
  - Catheter longevity limited by patency/infection



Dual-Lumen Tunneled Dialysis Catheter **Right IJ Tunneled Dialysis Catheter**

(Left) *Photograph demonstrates typical dual-lumen tunneled dialysis catheter. The optimal position for the Dacron cuff* → *is in the middle of the subcutaneous tunnel.* **(Right)** *Graphic shows a dual-lumen catheter* ⇨ *entering the internal jugular (IJ) vein* ⇨ *via a subcutaneous tunnel* ↪. *A Dacron cuff* → *on the catheter promotes tissue ingrowth within the tunnel, forming a barrier against infection.*



Right IJ Tunneled Dialysis Catheter **Left IJ Tunneled Central Venous Catheter**

(Left) *Chest radiograph after placement of a tunneled right IJ hemodialysis catheter* ↪ *shows that the catheter tip* → *is positioned in the upper right atrium, which is the desired location. There is no pneumothorax.* **(Right)** *Left IJ Hickman catheter* → *terminates at the superior cavoatrial junction* ⇨. *Note left basilar airspace disease* ↪.

TERMINOLOGY

Definitions

- **Tunneled catheter**: Intermediate- or long-term venous catheter introduced through subcutaneous tunnel into central veins of chest or abdomen
  - Subcutaneous tunnel forms natural infection barrier
  - Dacron cuff on catheter promotes tissue ingrowth
    - Secures catheter within tunnel
    - Enhances natural infection barrier of tunnel
  - Various tunneled catheters for range of indications
    - Hemodialysis (HD) catheter
    - Pheresis catheter
    - Tunneled peripherally inserted central venous catheter
      - Hickman catheter
      - Broviac catheter
      - Groshong catheter

PREPROCEDURE

Indications

- Intermediate- to long-term central venous access
  - Infusion therapy
    - Chemotherapy
    - Total parenteral nutrition
    - Caustic medications
  - Withdrawal/replacement therapy
    - Pheresis
    - Stem cell therapy
    - HD
      - HD in acute kidney injury
      - Bridging to arteriovenous (AV) HD fistula or graft
      - Final option in patients with failed AV fistulas or grafts
  - Central access while preserving peripheral access
    - Tunneled small-bore central venous catheter instead of peripherally inserted central catheter (PICC)
      - Indicated in chronic renal dysfunction patients
      - Preserves arm veins for AV HD fistula
      - Upper extremity venous occlusion/deep venous thrombosis/phlebitis

Contraindications

- Infection at insertion site
- Sepsis or unexplained fever > 24-hour duration
  - In septic patients, repeated negative blood cultures for > 48-72 hours advisable prior to tunneled catheter placement
  - Fever-free status for > 48-72 hours advisable prior to tunneled catheter placement
- Coagulopathy
  - International normalized ratio (INR) > 1.5; platelets < 50,000/μL
    - Target or central venous occlusion/deep venous thrombosis/phlebitis
- Allergy to material of catheter

Preprocedure Imaging

- Review any pertinent prior imaging study to confirm/exclude patency of target or central veins
  - Prior contrast-enhanced neck or chest CT
  - Prior target vein ultrasound imaging
- Check patency of target with ultrasound before starting

Getting Started

- Things to check
  - Clinical history/indication
    - Duration of treatment
    - Number of lumina needed
  - Coagulopathy: Consensus guidelines recommend INR < 1.5; platelets > 50,000/μL
  - Current medications
    - Warfarin: Goal to achieve INR < 1.5
    - Clopidogrel: Hold 5 days prior to procedure
    - Aspirin: Do not withhold
    - Low molecular weight heparin (therapeutic dose): Withhold same-day dose
  - Allergies
  - Laboratory results
    - Review coagulation panel, basic metabolic panel, CBC, blood cultures
  - Physical examination
    - Evaluate access site for irritation/infection
    - Evaluate for prior access
  - Limit oral intake for procedures requiring moderate sedation
    - NPO for 8 hours if sedation planned (hospital protocol specific)
    - Take any oral medications with sips of water
  - Written informed procedural consent
- Medications
  - 1% lidocaine or Xylocaine for local anesthesia
  - Heparin flush (100 IU/mL)
  - Preprocedural antibiotics: On individual basis
    - Recent publications do not support widespread prophylactic use of antibiotics
    - Procedure classified as clean procedure
    - Meticulous attention to sterility recommended
  - Sedatives/analgesics

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Access routes
    - Internal jugular vein (IJV) preferred
      - Right preferred over left IJV; provides short straight route to superior vena cava (SVC)
      - External jugular veins if IJVs occluded
    - Subclavian vein least preferred upper access route
      - Higher risk of pneumothorax, thrombosis, or symptomatic stenosis
      - Contraindicated in renal failure patients planned to undergo AV fistula or graft creation
    - Common femoral vein access
      - Used if no upper access route available
      - Highest incidence of infection
    - Translumbar venous access
      - Used if all other access routes unavailable
    - Transhepatic venous access

Procedure Steps

- **IJV access for tunneled catheter**
  - Obtain IJV access
  - After initial guidewire/sheath introduction
    - Advance 0.035" guidewire into SVC
    - Measure wire length from skin to right atrium
      - ☐ Determines intravascular catheter length
    - Place dilator over guidewire
  - Choose point for subcutaneous tunnel creation
    - Deltopectoral groove 4-5 cm below clavicle
    - Should not be too medial or in axilla
  - Anesthetize skin and along planned tunnel tract
  - Make small horizontal skin incision based on catheter diameter
  - Introduce tunneling tool through incision
  - Advance so tip exits beside dilator at venotomy site
    - Attach catheter tip to back of tunneler
    - Pull catheter through tunnel to venotomy site
      - ☐ Initially position cuff at distal end of tunnel close to venipuncture site
  - Exchange dilator over wire for peel-away sheath
    - Advance sheath under fluoroscopy into SVC
  - Remove inner dilator, wire from peel-away sheath
    - Occlude sheath if no hemostatic valve
      - ☐ Prevents bleeding/air embolus
  - Introduce catheter through peel-away sheath
    - Advance catheter into SVC
  - Peel sheath apart, keeping catheter in place
  - Apply gentle traction to achieve desired catheter position
    - Central venous catheter tip at superior cavoatrial junction
    - HD/pheresis catheters in upper right atrium
  - Venous lumen in HD/pheresis catheter must be lateral
  - Evaluate cuff position
    - Cuff should lie in middle of tunnel
    - At least 1-2 cm inside from skin incision
  - Evaluate catheter course for kinking
  - Aspirate/flush catheter lumen/lumina
  - Close venotomy site with skin glue, suture, or topical adhesive
  - Secure catheter to skin
    - 2-0 or 3-0 nonabsorbable suture
    - StatLock (Bard; Covington, GA)
  - Instill appropriate flush solution in lumen/lumina
    - HD/pheresis catheters typically receive heparin flush (100 IU/mL), volume dependent on catheter diameter and length
  - Apply sterile dressing
  - Obtain completion fluoroscopic spot image/chest radiograph
- **Subclavian vein access for tunneled catheter**
  - Obtain subclavian vein access
  - Peel-away sheath will enter subclavian vein
    - Otherwise, same steps as for IJV tunneled catheter
- **Common femoral vein access for tunneled catheter**
  - Obtain common femoral vein access
  - After initial guidewire/sheath introduction
    - Advance 0.035" guidewire into IVC
  - Create subcutaneous tunnel in upper thigh; direct toward femoral venous access point
    - Same steps same as for IJV tunneled catheter
  - Introduce catheter through peel-away sheath
    - Place catheter tip at inferior cavoatrial junction
  - Remaining steps same as for IJV tunneled catheter

Alternative Procedures/Therapies

- Radiologic
  - Nontunneled central catheter
    - Temporary indication; infection risk if long term
  - PICC
    - Lower flow rates than central catheters
    - Avoid in renal failure patients; preserve arm veins

POST PROCEDURE

Things To Do

- Observe access site for bleeding or hematoma
  - Elevate head of bed after upper venous access if possible
    - Decreases venous pressure at access site
    - Decreases bleeding/hematoma risk
- If concern for pneumothorax
  - Initially evaluate lung fluoroscopically
  - Obtain AP upright inspiratory/expiratory chest film
  - Auscultate breath sounds with stethoscope
- After catheter insertion
  - Obtain fluoroscopic spot image
    - Document catheter course, tip position
  - Obtain AP upright inspiratory/expiratory chest film
    - Excludes pneumothorax, documents catheter course and tip position

Things To Avoid

- If catheter externally secured with suture
  - Avoid puncturing catheter with suture needle
  - Do not "crimp" catheter with purse string
- Positioning of catheter tip deep in right atrium
  - May cause arrhythmia
- Air embolism
- Instruct patient not to immerse catheter in water
  - May cause infection

Management of Impaired Tunneled Catheters

- **Catheter malfunction**
  - Check catheter position on chest radiograph
  - Attempt to aspirate catheter
  - Inject contrast under fluoroscopy
    - If thrombus or fibrin at catheter tip
      - ☐ Administer thrombolytic agent (e.g., 2 mg of tPA) through catheter lumen/lumina
      - ☐ May mechanically strip fibrin from tip using snare catheter or perform fibrin sheath angioplasty; often only temporary solution
      - ☐ Exchange/replace catheter
    - If malpositioned catheter
      - ☐ May attempt repositioning with guidewire
      - ☐ Exchange/replace/remove catheter
    - If central venous thrombosis
      - ☐ Thrombolysis through catheter
      - ☐ Systemic anticoagulation

-
  -
    -
      - If catheter functional, leave indwelling during anticoagulation unless access no longer needed
      - If catheter removed from thrombosed vein, that access site usually no longer accessible
- **Catheter infection**
  - Spectrum ranges from fever with no obvious cause to purulent discharge from tunnel
    - If transient bacteremia, consider catheter exchange
      - Antibiotic regimen
    - Septicemia/positive blood cultures
      - Catheter removal and tip culture
      - Antibiotic regimen
      - 48-hour afebrile period with negative blood cultures before catheter reinsertion
- **Catheter exchange**
  - Indications
    - Transient bacteremia
    - Nonfunctioning/malfunctioning catheter
  - Procedure steps
    - Sterilely prepare skin/external portion of catheter
    - Aspirate heparin from catheter lumen/lumina
    - Locally anesthetize catheter tunnel
    - Use hemostat to dissect
      - Along catheter course; scar tissue around cuff
    - Insert stiff guidewire(s) through catheter lumen/lumina
    - Pull catheter from tunnel with steady traction
      - Be certain not to lose guidewire access
    - For malfunctioning dialysis catheter, inject contrast through slightly retracted catheter
      - Helps to visualize fibrin sheath
    - If fibrin sheath present
      - Remove catheter over guidewire
      - Introduce 8-Fr or 9-Fr sheath
      - Perform angioplasty of entire fibrin sheath with 8 x 4 or 10 x 4 balloon; possible association exists between balloon disruption of fibrin sheath and late-onset (3 years) central venous stenosis; do not overdilate
      - Repeat contrast injection
      - Remove sheath over guidewire
    - Introduce new catheter over guidewire(s)
      - If catheter will not track, place peel-away sheath over guidewire; insert catheter through sheath
    - Fluoroscopically confirm catheter tip position
- **Catheter removal**
  - Indications
    - Catheter infection
    - Sepsis of unknown origin; catheter possible source
    - Catheter malfunction/fracture/no longer needed
  - If central catheter still needed, confirm other access routes available/patent before catheter removal
  - Procedure steps
    - Same initial steps as for catheter exchange
    - After dissecting cuff/catheter free from tunnel
      - Pull catheter from tunnel with steady traction
    - Send tip for culture/sensitivity/Gram stain if appropriate
    - Apply pressure over venotomy site for 10 minutes
      - Seat patient upright to decrease venous pressure

OUTCOMES

Complications

- Immediate/periprocedural complication(s)
  - Bleeding or hematoma (incidence: 0.2%)
    - Management of bleeding from tract
      - Sitting patient upright after insertion minimizes venous pressure, decreases bleeding
      - Apply digital pressure on venipuncture site and along catheter tract
      - Pack tract with Gelfoam adjacent to catheter
      - Use liquid hemostatic agent, such as D-Stat Flowable (Vascular Solutions; Minneapolis, MN)
  - Air embolism (incidence < 1%)
    - Can be massive with large-bore HD/pheresis catheters
      - Place in left lateral decubitus position; traps air in right atrium
      - Institute high-flow oxygen
      - If severe, place catheter in atrium, aspirate air
      - Cardiopulmonary resuscitation may be required
  - Pneumothorax (incidence: 1%)
    - Highest rate with subclavian venous access
    - Treatment with chest tube placement if symptomatic or enlarging
  - Arterial puncture (carotid puncture incidence: 1.7%)
    - If dilator/sheath/catheter placed
      - Consider emergent consultation with vascular surgery prior to withdrawal
      - Surgical repair or arteriography/stenting may be necessary
  - Failure to insert catheter (incidence: < 1%)
  - Guidewire or catheter-induced arrhythmia
- Delayed complication(s)
  - Infection (incidence: 5-10%; increases with time)
    - Catheter colonization
    - Catheter-related blood stream infections
    - Exit site infections
  - Catheter malfunction (incidence: 10-20%)
    - Unable to flush/aspirate: Most common problem
      - Usually from fibrin sheath in/around catheter tip
      - Venous thrombosis (symptomatic: 5-15%)
      - Catheter tip malposition
      - Catheter kink
  - Symptomatic venous stenosis

Expected Outcomes

- > 95% success rate in tunneled catheter placement
- Catheter longevity limited by patency/infection

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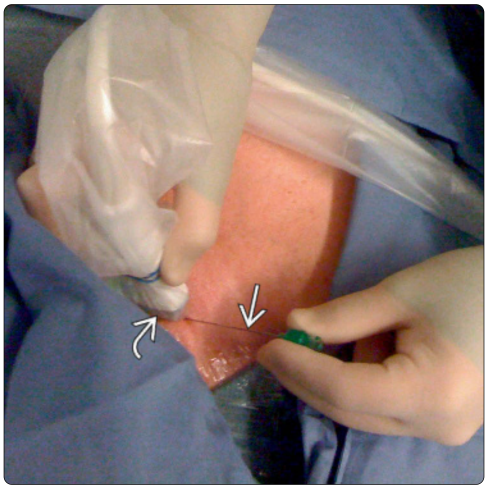
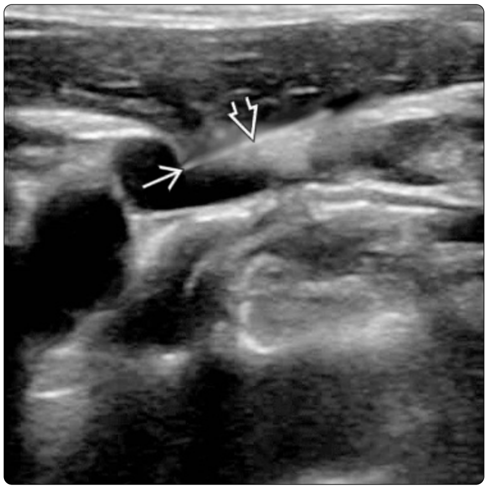
2. Patel IJ et al: Consensus guidelines for periprocedural management of coagulation status and hemostasis risk in percutaneous image-guided interventions. J Vasc Interv Radiol. 23(6):727-36, 2012
3. Heberlein W: Principles of tunneled cuffed catheter placement. Tech Vasc Interv Radiol. 14(4):192-7, 2011
4. Ni N et al: Association between disruption of fibrin sheaths using percutaneous transluminal angioplasty balloons and late onset of central venous stenosis. Cardiovasc Intervent Radiol. 34(1):114-9, 2011
5. Haas B et al: Large-bore tunneled central venous catheter insertion in patients with coagulopathy. J Vasc Interv Radiol. 21(2):212-7, 2010

(Left) *Intraoperative photograph obtained during ultrasound-guided jugular venous access for tunneled catheter placement shows an ultrasound probe ↪ has been used to identify the IJ vein. A micropuncture needle → has been introduced from an anterolateral approach.* **(Right)** *During ultrasound-guided venous puncture, the tip of an echogenic needle ⇨ "tents" the vein wall → into the lumen. Continued pressure while advancing the needle allows puncture of the wall and lumen entry.*

Step-by-Step: IJ Tunneled Catheter Placement (Venous Access)

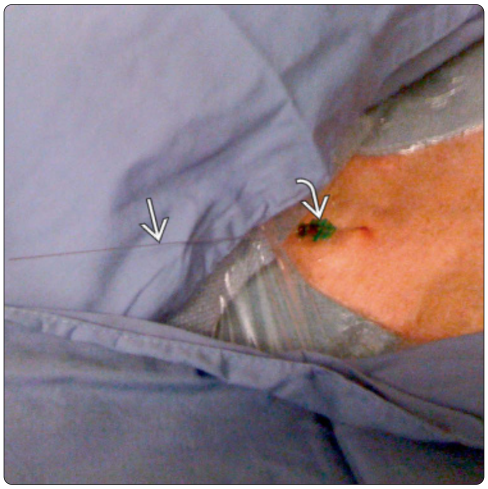


Step-by-Step: IJ Tunneled Catheter Placement (Venous Access)

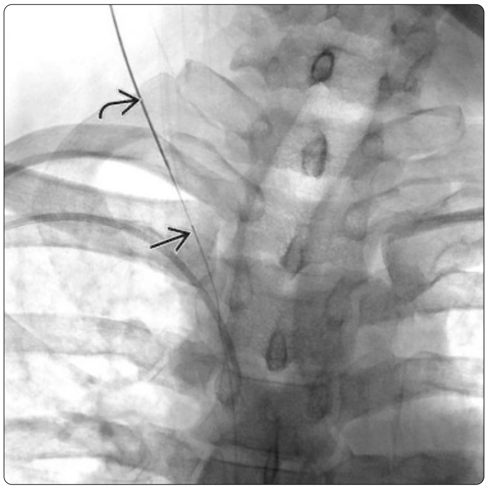


(Left) *Intraoperative photograph shows that a microwire → has been introduced via the micropuncture needle ↪ following blood return from the needle hub. The wire will be advanced into the superior vena cava (SVC).* **(Right)** *Spot radiograph shows the microwire → that has been inserted through the micropuncture needle ↪. The course of the guidewire is monitored fluoroscopically during insertion through the needle in order to ensure that it enters the SVC.*

Step-by-Step: IJ Tunneled Catheter Placement (Microwire Advancement)

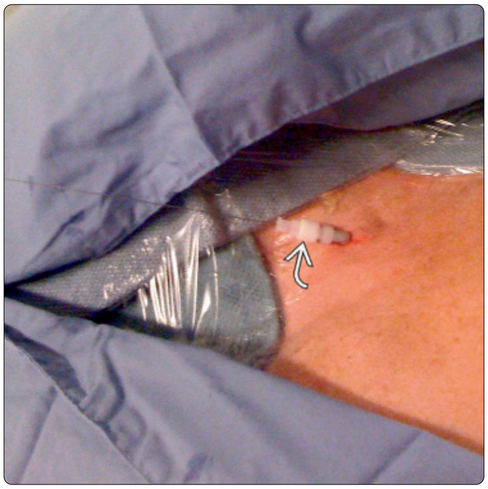


Step-by-Step: IJ Tunneled Catheter Placement (Microwire Advancement)

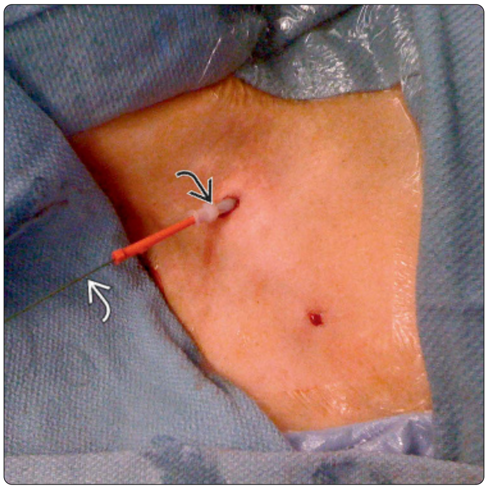


(Left) *Intraoperative photograph after removal of the micropuncture needle shows that a transitional dilator ↪ has been placed over the microwire. This dilator has an inner component that accepts the microwire and an outer sheath that accepts a standard guidewire.* **(Right)** *Intraoperative photograph after removal of microwire and inner component of the transitional dilator shows the outer sheath ↪, through which a standard guidewire ↪ has been introduced.*

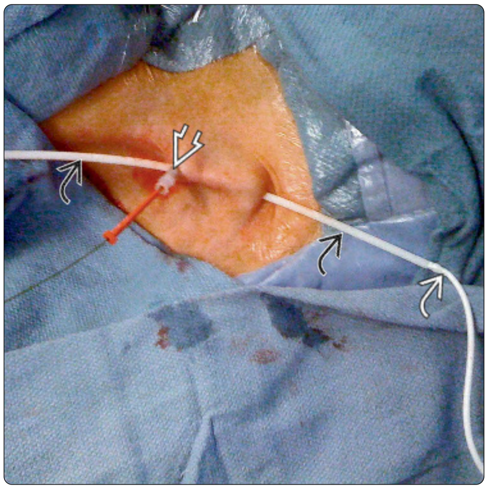
Step-by-Step: IJ Tunneled Catheter Placement (Transitional Dilator)



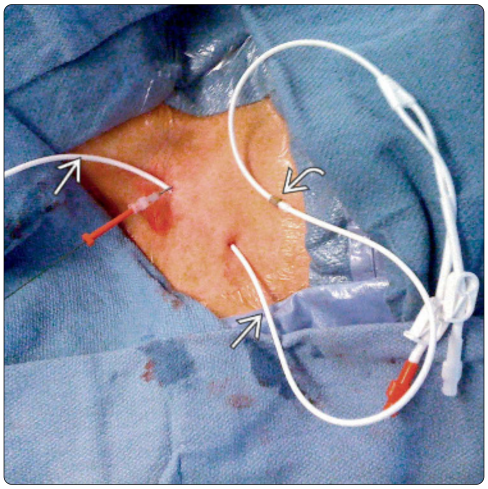
Step-by-Step: IJ Tunneled Catheter Placement (Standard Guidewire)



Step-by-Step: IJ Tunneled Catheter Placement (Tunnel Creation)

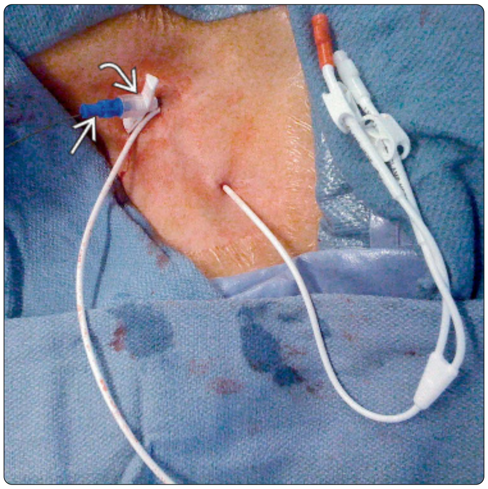


Step-by-Step: IJ Tunneled Catheter Placement (Catheter Through Tunnel)

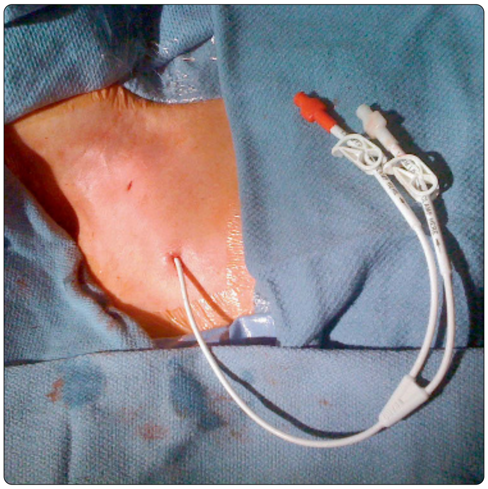


(Left) *Intraoperative photograph shows that the catheter tip* ↪ *is attached to a tunneling device* ⤻ *that has been used to create a subcutaneous tunnel. The tunneler exits from the soft tissues immediately adjacent to the jugular venous access sheath* ⇨ *and guidewire.* **(Right)** *The catheter* ➡ *has been pulled through the newly created subcutaneous tunnel. The tunnel must be of sufficient length that the cuff* ↪ *on the catheter lies at least 1-2 cm within the tunnel.*

Step-by-Step: IJ Tunneled Catheter Placement (Cuff Within Tunnel)

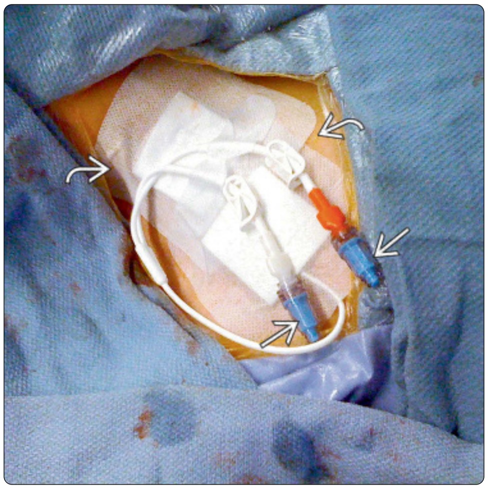


Step-by-Step: IJ Tunneled Catheter Placement (Catheter Venous Insertion)

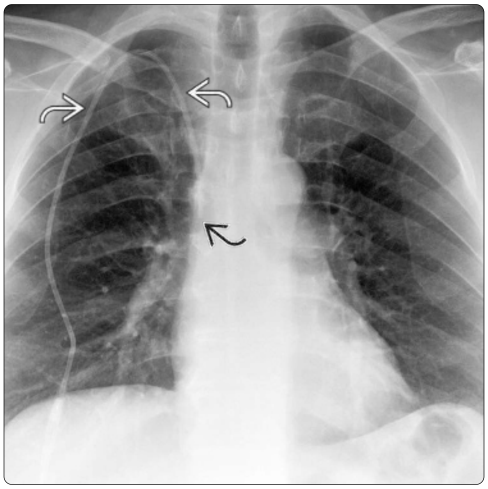


(Left) *The cuff has been pulled into the subcutaneous tunnel and is no longer exposed. The initial access sheath has been replaced with a peel-away sheath* ↪*. After the inner dilator* ➡ *is removed, the tip of the adjacent catheter will be introduced and will be positioned just below the cavoatrial junction. The sheath will be peeled apart, leaving the catheter in place.* **(Right)** *After peel-away sheath removal, the tunneled catheter has a completely subcutaneous course, providing a natural barrier to infection.*

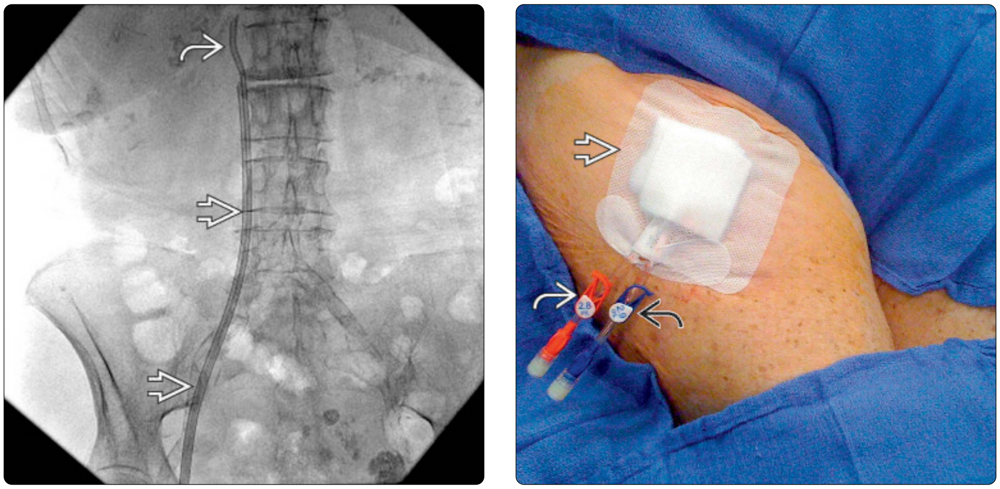
Step-by-Step: IJ Tunneled Catheter Placement (Flush Lumina, Apply Dressing)



Step-by-Step: IJ Tunneled Catheter Placement (Final Radiograph)



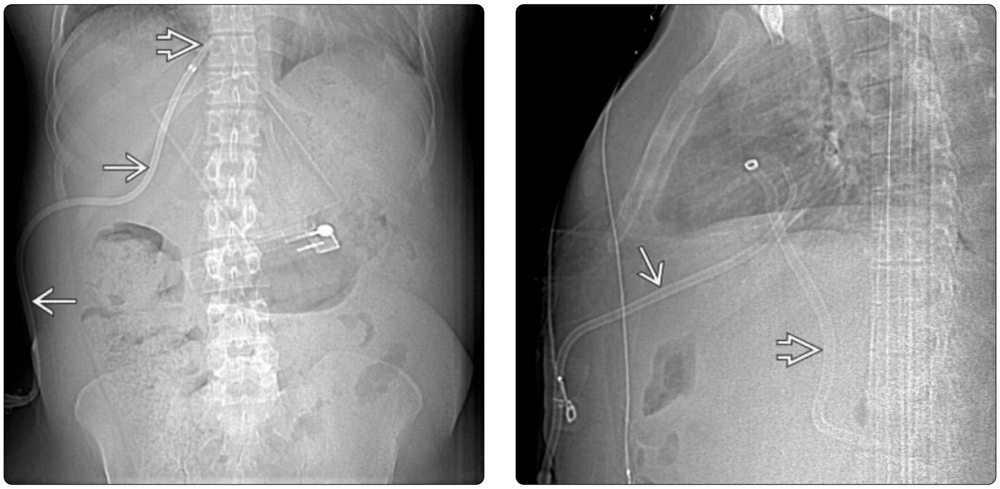
(Left) *Postinsertion photograph shows that a sterile dressing* ↪ *has been applied and that sterile caps* ➡ *have been attached to the catheter hubs. Prior to dressing application, both lumina were flushed, the catheter was secured to the skin with purse-string sutures, and the venotomy was closed.* **(Right)** *Chest radiograph after tunneled catheter placement shows no kinks in the catheter course* ↪*, a good tip position* ⤻*, and no pneumothorax.*



Femoral Venous Tunneled Catheter

Femoral Venous Tunneled Catheter

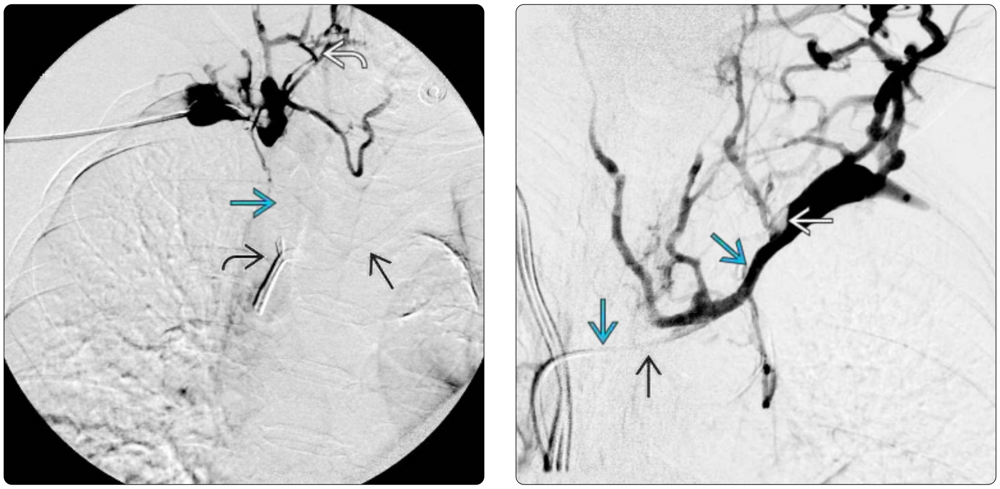
(Left) *Fluoroscopic spot radiograph shows a tunneled hemodialysis catheter ⇨ that has been placed from a right femoral vein approach. The catheter tip ↪ is in the inferior vena cava above the renal veins. Femoral venous access is used when there is upper extremity central venous occlusion.* **(Right)** *Intraoperative photograph following placement of a tunneled right femoral hemodialysis catheter shows the dual-lumen catheter ↪ ↪. Catheter has been secured to the skin, and a sterile dressing ⇨ has been applied.*



Transhepatic Tunneled Dialysis Catheter

Transhepatic and Translumbar Catheters

(Left) *CT scout image demonstrates transhepatic tunneled dialysis catheter → with the tip at the superior cavoatrial junction ⇨.* **(Right)** *Lateral CT scout view demonstrates transhepatic dialysis catheter → placed for emergent dialysis due to malfunction of the translumbar dialysis catheter ⇨. Both catheters terminate in the right atrium.*

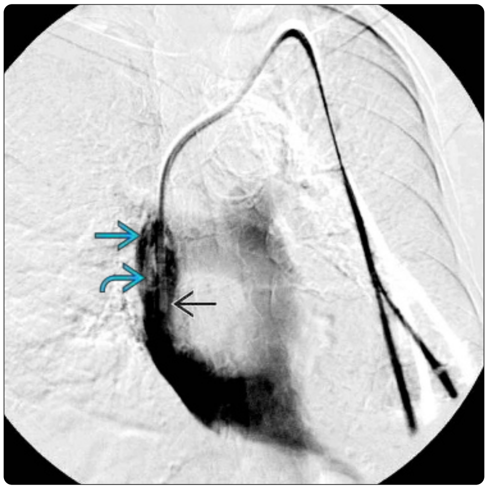


Catheter-Induced Central Venous Occlusion (Right Brachiocephalic)

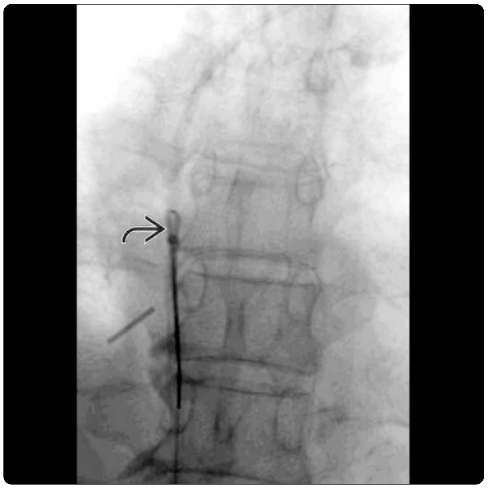
Catheter-Induced Central Venous Occlusion (Left Brachiocephalic)

(Left) *Venogram shows right brachiocephalic → vein occlusion from a prior right hemodialysis catheter. Venous collaterals ↪ are noted in the neck. The left-sided tunneled hemodialysis catheter → was nonfunctional, likely because of the malpositioned tip ↪.* **(Right)** *A venogram shows a tunneled catheter → coursing through a centrally occlusive left brachiocephalic vein →, which contains a small focal thrombus →. If this catheter is removed rather than exchanged, this access route will be lost.*

Catheter Malfunction: Fibrin Sheath (Diagnostic DSA)

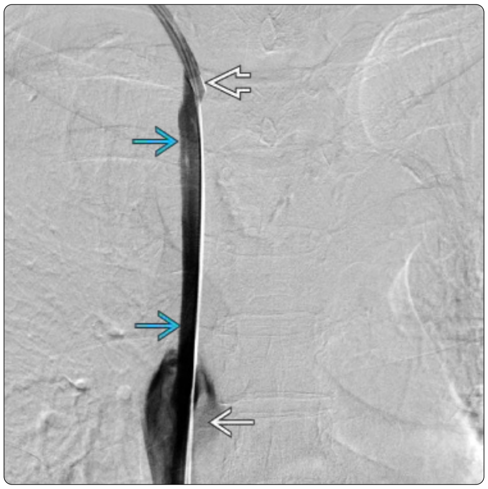


Catheter Malfunction: Fibrin Sheath (Fibrin Sheath Stripping)

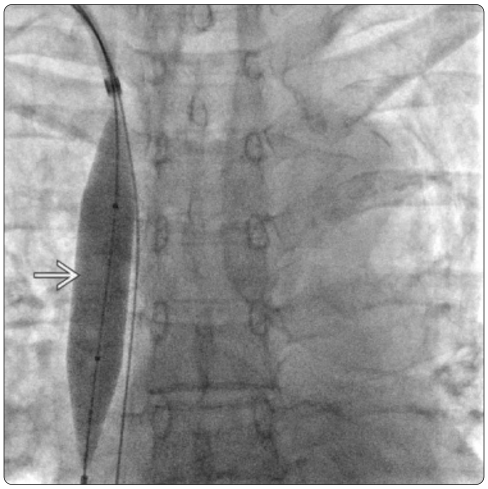


(Left) *DSA of contrast injection through the lumina of a malfunctioning catheter shows that contrast courses retrograde → because of thrombus or fibrin ↷ surrounding the catheter tip →. Administering a thrombolytic agent through the lumen may restore patency if the catheter is occluded by thrombus.* **(Right)** *If a tunneled catheter is occluded by surrounding fibrin, encircling the catheter with a gooseneck snare ↷ and stripping the fibrin off of the catheter may be used to restore patency.*

Catheter Malfunction: Fibrin Sheath (Diagnostic Central Venogram)

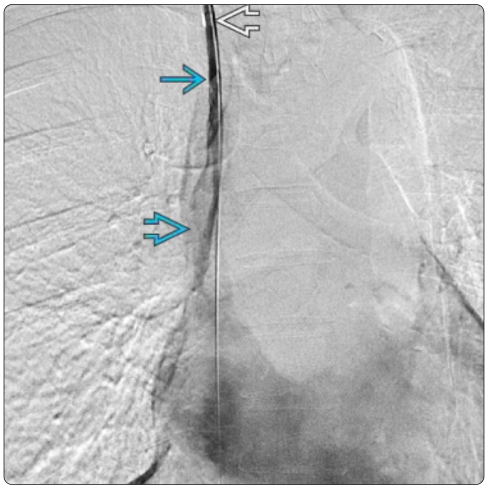


Catheter Malfunction: Fibrin Sheath (Angioplasty)

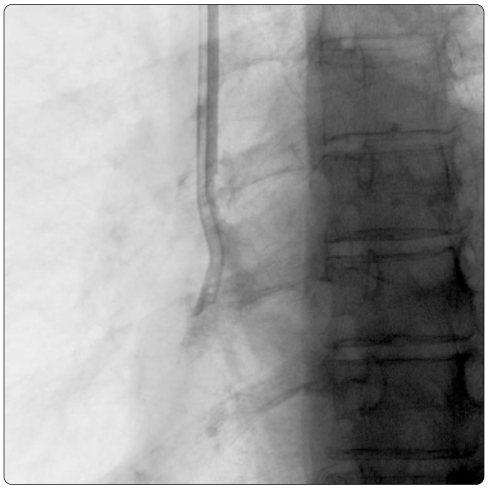


(Left) *A DSA was performed through a vascular sheath ⇨ advanced over a wire during a right IJ catheter exchange. A fibrin sheath → was present in the shape of a catheter cast, extending into the right atrium ⇨. The guidewires course into the inferior vena cava (not visualized).* **(Right)** *The fibrin sheath was disrupted with a 12-mm-diameter angioplasty balloon →. This balloon may be a bit larger than needed. Avoid overdilating in cases devoid of central venous stenosis.*

Catheter Malfunction: Fibrin Sheath (Central Venogram Post Angioplasty)



Catheter Malfunction: Fibrin Sheath (Catheter Replacement)



(Left) *Postangioplasty DSA through the vascular access sheath ⇨ demonstrates disruption of the fibrin sheath in the SVC ➡. The fibrin sheath, however, is still intact in the upper brachiocephalic vein →.* **(Right)** *A new tunneled dialysis catheter was placed over the existing wires with the catheter tip terminating in the upper right atrium. The catheter functioned normally at this time.*

Ports

KEY FACTS

TERMINOLOGY

- **Port catheter**: Totally implantable central venous access device consisting of subcutaneous access port and venous catheter attachment
- Implantation sites
    - Chest port: Requires patent jugular or subclavian veins
    - Arm port: Appropriate for patient with bilateral mastectomy, future bilateral chest radiotherapy
    - Lumbar port: Alternative if occluded central veins
- Port choice
    - Power port: Frequent CECT
    - Double-lumen port: Medications/total parenteral nutrition (TPN) required in addition to chemotherapy
    - Low-profile port: Designed for pediatric or cachectic patient/peripheral insertion
    - 12-Fr Vortex port: For photopheresis

PREPROCEDURE

- Review indications to determine appropriate implantation site
- Review prior imaging for patency of planned venous access
- Review medication list and laboratory values

PROCEDURE

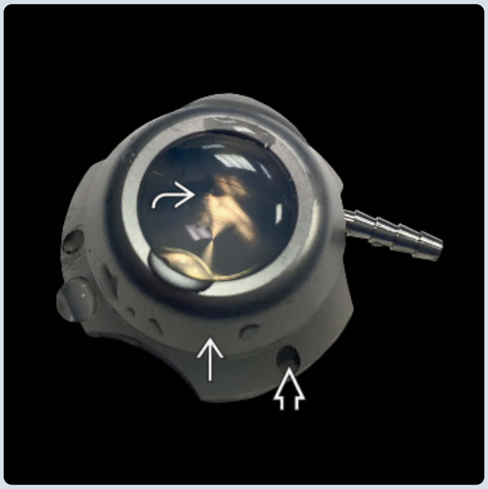
- **Chest port**: Obtain internal jugular vein access
    - Introduce 8-Fr peel-away sheath over wire
    - Create subcutaneous pocket in anterior chest wall and tunnel catheter to venotomy site
    - Introduce catheter through peel-away sheath
    - Cut catheter, secure to port; place port in pocket
    - Close pocket/skin incision

OUTCOMES

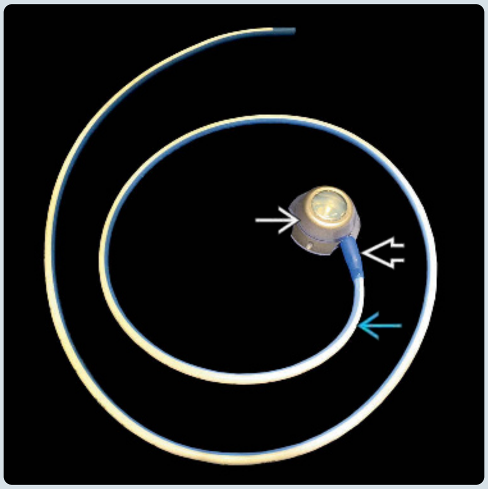
- Complications
    - Chest wall hematoma: Most common
    - Infection: 5.6% overall

(Left) *An example of a Smart Port (AngioDynamics, Latham, NY) is shown. This is a typical appearance of a port, with a metallic reservoir chamber ➡, covered by an accessible silicon disc ↷. Silicon-filled holes ⇨ allow optional suturing of the port to the chest wall.* **(Right)** *The port catheter ➡ has been attached to the reservoir ➡, and a connector ring ⇨ slid in place to help secure the connection. The catheter is usually cut to the appropriate length prior to making this connection.*

Port

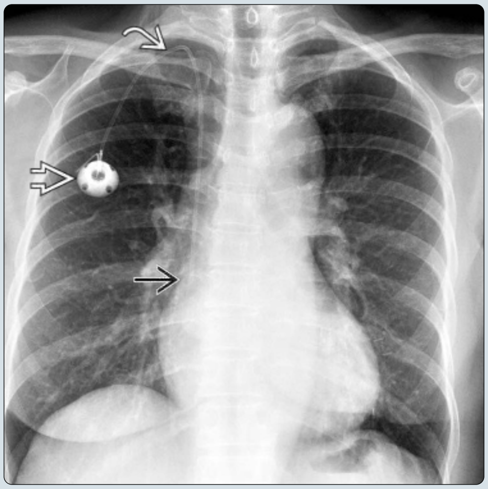


Port Catheter

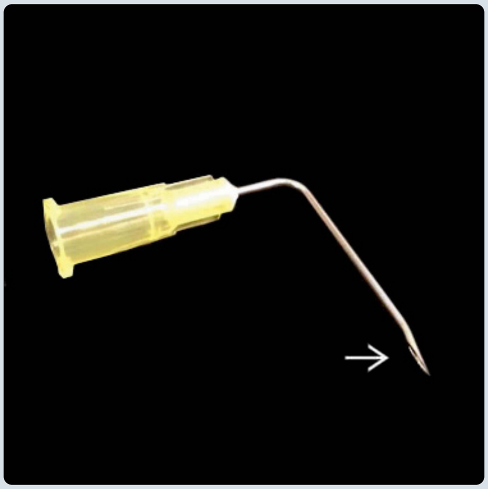


(Left) *Radiograph shows a single-lumen chest port ⇨ with the catheter exhibiting a gentle curve ↷ as it courses to point of venous entry into the internal jugular vein. The catheter tip position → at the cavoatrial junction is optimal.* **(Right)** *Huber needles are specially designed with a side-facing lumen ➡, not an end hole. This allows Huber needles to repeatedly penetrate the silicon cap of a port without coring or cutting the silicone.*

Appropriate Appearance of Chest Port



Huber Access Needle



TERMINOLOGY

Definitions

- **Port catheter**: Totally implantable central venous access device consisting of subcutaneous access port and venous catheter attachment
  - Used to provide long-term central venous access
    - Typically needed for months to years
  - Port reservoir construction
    - Silicon disc in plastic or titanium body
    - Permits 1,000-2,000 accesses (19- to 22-g Huber point noncoring needles)
  - Catheter construction
    - 6- to 16-Fr catheter sizes
    - Silicon rubber/polyurethane material
    - Preattached or attachable
    - Groshong valve: Flushes with normal saline only
      - Advantageous if heparin allergy
  - a.k.a.
    - Implantable subcutaneous port
    - Port-a-cath
    - Venous access device
- **Port configurations/specifications**
  - Single- or dual-lumen port
    - Power injectable: Accommodates contrast injection rates used in CECT
      - Standard port placed at many institutions
    - Low profile: Ideal for cachectic/thin patients, arm placement
      - Smaller port height, decreased bulge under skin
      - Decreased risk of port erosion
    - Mini/small profile: Pediatric/small patients
      - Allows small pocket/less surrounding soft tissue
    - Dual lumen: Patients requiring medications/chemotherapy in addition to total parenteral nutrition (TPN)
      - 1 lumen often dedicated to TPN delivery

PREPROCEDURE

Indications

- **General**
  - Long-term central venous access
    - Chemotherapy (most common)
    - TPN
    - Antibiotic therapy
    - Chronic blood product administration
- **Chest port**
  - Preferred/standard placement site for port
  - Requires patent internal/external jugular vein
    - Catheter usually placed via internal jugular vein
    - Catheter may be inserted via subclavian vein
      - Theoretical higher complication risk (e.g., pneumothorax, venous thrombosis)
      - Avoid in renal or hemodialysis patients; preserve axillary/subclavian veins for future access
  - Requires patent superior vena cava (SVC)
    - Catheter tip placed at superior cavoatrial junction
  - Requires sufficient chest wall soft tissue for pocket
  - No further chest radiotherapy/surgery planned
    - Radiotherapy to port placement site limits healing/causes higher dehiscence rate
    - Subcutaneous port may obscure target lesion in chest
- **Arm port**
  - Appropriate for patient with bilateral mastectomy
  - Consider if possible future bilateral mastectomy, chest radiotherapy
    - Requires patent SVC/arm veins
- **Lumbar port**
  - Placed if thrombosed arm/neck/central veins
    - Requires patent inferior vena cava (IVC)
    - Ideally, do not place in presence of IVC filter

Contraindications

- Sepsis or unexplained fever > 24-hour duration
  - In septic patients, repeated negative blood cultures for > 48 hours advisable prior to port placement
- Active skin infection
- Coagulopathy
  - International normalized ratio (INR) > 1.5; platelets < 50,000/µL
- Target access vein or central vein occlusion
- Bevacizumab (Avastin) administration 2 weeks prior/post port placement
  - Bevacizumab is angiogenesis inhibitor
    - Increased nonhealing/port erosion/dehiscence risk

Preprocedure Imaging

- Review any pertinent prior imaging study
  - NECT and CECT
    - Preoperative CT abdomen is recommended for translumbar port placement to confirm anatomy
  - Prior venous US studies

Getting Started

- Things to check
  - Clinical history/indication
    - Prior history of central venous access or port catheter placement
      - Increased risk or occluded access or central veins
    - Specifics regarding malignancy
      - Prior mastectomy/neck dissection affect access/port implantation site(s)
  - Current/future treatment plan
    - Planned radiation to port field may compromise healing, increase risk of port erosion/dehiscence; port may obscure target lesion in chest
    - No bevacizumab 2 weeks prior/post procedure
      - Increased risk of dehiscence if continued
  - Current medications
    - Withhold anticoagulant/antiplatelet medication
    - Warfarin: Goal to achieve INR < 1.5
    - Clopidogrel: Withhold 5 days prior to procedure
    - Aspirin: Do not withhold
    - Low molecular weight heparin (therapeutic dose): Withhold same day dose
    - Bevacizumab: Withhold 2 weeks prior/post procedure
  - Allergies
    - Medications: Heparin, antibiotics, sedatives, and analgesics
    - Contrast media

    - Catheter material: Silicone, polyurethane
    - Latex, tape, bandages, etc.
  - Laboratory results
    - Review coagulation panel, CBC
  - Limit oral intake for 8 hours preprocedure
    - Take any oral medications with sips of water
  - Physical examination
    - Evaluate access site for irritation/infection
    - Confirm adequate soft tissue to implant port
      - Inadequate soft tissue may predispose to wound dehiscence/skin necrosis with port exposure
    - Evaluate access site for evidence of prior access
  - Written informed procedural/sedation consent
- Medications
  - Local anesthetic
    - 1% lidocaine or Xylocaine for skin
    - 1% lidocaine with epinephrine for port pocket
  - Preprocedural antibiotics
    - Ancef 1 g IV: Single dose prior to procedure
    - Clindamycin 600 mg IV: Known penicillin allergy
  - Sedatives/analgesics for moderate sedation
  - Heparin
  - Heparinized saline
- Equipment list
  - Venipuncture
    - Chest/arm port: 5-Fr micropuncture set
    - Lumbar port: 22-g Chiba/18-g trocar needle
  - Guidewires
    - 0.018" microwire
    - 0.035" 3-J guidewire or short Amplatz
    - 0.035" stiff Glidewire or Amplatz (lumbar port)
  - Sheaths/catheters
    - 6-Fr peel-away sheath (arm port)
    - 8-Fr peel-away sheath (chest port)
    - Lumbar port
      - 5-Fr pigtail catheter
      - Introducer set
      - 8-Fr 30-cm peel-away sheath
  - Port choice: Power injectable, dual lumen, low profile, mini profile, etc.
    - Based on patient's body habitus, therapeutic needs addressed by port
    - Many styles available, availability often dependent on medical supplier contracting with institution

PROCEDURE

Patient Position/Location

- Chest port: Supine
  - Sterilely prepare/drape skin of neck/upper chest
- Arm port: Supine/arm abducted in anatomical position
- Lumbar port: Supine and right anterior oblique positions

Equipment Preparation

- Prepare/flush catheters/sheaths/port reservoir

Procedure Steps

- **General**
  - Sterilely prepare/drape skin
    - Administer 1% lidocaine local anesthesia
  - Perform venipuncture for catheter access
    - Chest and arm ports: US-guided venipuncture with 5-Fr micropuncture set
    - Translumbar port: Fluoroscopic-guided puncture with 22-g Chiba needle
  - Perform blunt dissection of soft tissues at venipuncture site with hemostat to prevent catheter kinking/tagging in dermis
- **Port pocket creation**
  - Administer 1% lidocaine or Xylocaine for skin anesthesia
    - 1% lidocaine with epinephrine for port pocket
  - Use #15 scalpel to make skin incision
    - Sufficient length to accommodate chosen port
  - Use hemostat/clamp; bluntly dissect to fascia
    - Should be large enough to accommodate port
      - Should not be too large; port should fit snug
      - Large pocket allows excessive port movement
      - Perform frequent trial port insertions to ensure adequate pocket size
  - Suturing port in pocket (optional): Not usually necessary if port tight in pocket
    - Place nonabsorbable anchoring sutures through silicon-filled holes at edges of port, anchoring medial and lateral aspects of port
    - Makes removal more difficult
  - Do not tighten sutures or place port into pocket
    - Keep port outside pocket until catheter connected
- **Subcutaneous tunnel creation/catheter insertion**
  - Anesthetize tract with 1% lidocaine or 1% lidocaine with epinephrine
  - Use metal/plastic tunneling device
    - Usually packaged/included with proprietary port
  - Attach catheter tip to base of tunneling device
  - Introduce tip of tunneler into subcutaneous tissues
    - Should enter from margin of pocket
  - Advance tunneler through subcutaneous tissues from pocket to venotomy site
  - Tunneler tip should exit adjacent to sheath
    - Ensure no skin bridge between catheter/sheath
    - Remove catheter tip from base of tunneling device
  - Alternatively may use back tunneling; attach tunneling device to back of catheter
    - Introduce tip of tunneler into subcutaneous tissues entering adjacent to venous access sheath
      - Advance tunneler through subcutaneous tissues from venotomy site to pocket
      - Remove catheter end from tunneling device
  - Remove guidewire/dilator from peel-away sheath
  - Introduce catheter tip into sheath
    - Advance catheter until tip in appropriate position
      - Confirm fluoroscopically
  - Peel sheath apart; remove
    - Consider fluoroscopic imaging while peeling sheath to ensure catheter position unchanged
- **Catheter connection to port**
  - After tunneling catheter and placing in sheath, adjust catheter tip to proper position
    - Between lower 1/2 SVC and superior 1/2 right atrium
  - Slide connector piece proximal, pinch catheter tightly with fingers, cut catheter to appropriate length
  - Connect catheter to port stem

-
  -
    - Secure catheter to stem using connector/locking ring
  - Flush port before placing in pocket
    - Ensures intact connection to catheter, without leakage
- **Securing port/closing pocket**
  - Place port into pocket
  - Tie anchoring sutures (optional)
  - Close subcutaneous pocket
    - Use interrupted 3-0 absorbable subcutaneous sutures
    - Close incision with interrupted/running 3-0 Vicryl subcuticular sutures
    - Place Steri-Strips over incision
    - **Caution**: Avoid piercing catheter with suture needle
  - Close venotomy: Steri-Strips, subcuticular suture or glue
  - Place sterile dressing
- **Chest port insertion**
  - Obtain internal jugular vein access
    - Use micropuncture access set/US guidance
      - Place US probe just cephalad to clavicle
      - Approach internal jugular vein laterally to create venipuncture at the lateral wall of vein
    - Advance transitional dilator over 0.018" guidewire
    - Exchange microwire for 0.035" guidewire (e.g., 3J, Amplatz)
  - Perform serial dilatation of venotomy site
  - Introduce 8-Fr peel-away sheath over guidewire
  - Create subcutaneous pocket in anterior chest wall
  - Create subcutaneous tunnel for catheter
  - Introduce catheter through peel-away sheath
    - Peel away sheath
  - Determine appropriate site to cut catheter
    - Position catheter tip at cavoatrial junction
  - Ensure connector ring on catheter central to cut site
  - Cut catheter to appropriate length, grasping catheter tightly with fingers
  - Connect catheter to port, secure with connector ring
  - Insert port into pocket
  - Obtain percutaneous port access with noncoring needle
    - Confirm that port flushes/aspirates
    - Fill port with heparin: 4- to 5-mL heparin flush (100 U/mL)
    - Access needle can be removed or left in patients requiring chemotherapy or infusions
  - Close skin with subcutaneous/subcuticular sutures and Steri-Strips or skin glue
  - Close venotomy site with Steri-Strips or skin glue
- **Arm port insertion**
  - Obtain US-guided basilic/brachial vein access
  - Pass 0.035" guidewire centrally
  - Place 6-Fr peel-away sheath over guidewire
  - Create pocket anteromedial to biceps
  - Back-tunnel technique
    - Advance catheter centrally; tip at cavoatrial junction
    - Back-tunnel catheter through subcutaneous tissues; connect to port
      - Port stem oriented toward central veins
  - Forward-tunnel technique
    - Tunnel from lower margin of pocket
    - Tunnel forms gentle curve toward sheath
      - U-shaped course from pocket to sheath
      - Catheter should exit adjacent to sheath
    - Connect catheter to port
      - Port stem oriented toward hand
  - Place/secure port in pocket
  - Tie anchoring sutures
  - Close pocket/skin incision
- **Lumbar port insertion**
  - Patient in supine position
    - Obtain right common femoral vein access (optional) to provide target for translumbar venous access
    - Place 5-Fr pigtail catheter in mid/lower IVC
      - Perform DSA IVC-gram
    - Position catheter with pigtail at renal vein level
      - Use adhesive to secure catheter to groin
  - Obtain infrarenal IVC access
  - Confirm blood return: Advance 0.018" wire into IVC
  - Advance 7-Fr introducer into IVC
  - Remove inner stiffener and guidewire
    - Inject contrast via introducer sheath
      - Confirm intravenous position
    - Advance 0.035" stiff guidewire into upper IVC
  - Serially dilate tract to 8-Fr diameter
    - Place 8-Fr peel-away sheath over wire into IVC
  - Create subcutaneous pocket
    - Pocket should be located laterally
      - Uncomfortable if port in flank/back
    - Pocket should overlie bone
      - Inferior right costal margin; over right iliac crest
      - Easier to access port if underlying bone support
  - Tunnel catheter from pocket to peel-away sheath
  - Advance catheter through sheath into IVC
    - Position tip at junction of IVC/right atrium
    - Remove peel-away sheath
  - Cut catheter to appropriate length, connect to port
  - Place/secure port in pocket
  - Tie anchoring sutures
  - Close pocket/skin incision
  - Return patient to supine position
    - Remove 5-Fr pigtail catheter over 0.035" guidewire
      - Ensures no displacement of port catheter
    - Use manual compression to obtain hemostasis
- **Fluoroscopic port check**
  - Evaluation when unable to aspirate/flush port
  - Access port with Huber needle
  - Inject contrast medium; monitor fluoroscopically
  - Obtain DSA images
    - Evaluate catheter tip position
    - Exclude fibrin sheath/thrombus around catheter
- **Port removal**
  - Make transverse incision overlying pocket
    - May use prior healed incision as target
    - Do not cut too deep, avoid cutting port catheter
    - Bluntly dissect catheter free, place hemostat under catheter to raise catheter
    - Gently dissect away fibrin sheath encasing catheter
    - Pull catheter from tunnel, hold pressure at neck
  - Dissect port free from pocket
    - Typically encased in fibrous scar tissue
    - Cut off and remove anchoring sutures (if present)

  - Close pocket in 2 layers using 3-0 Vicryl
    - If removing infected port
      - Do not close pocket; pack with iodoform
      - Allow healing by 2° intention

Alternative Procedures/Therapies

- Surgical
  - Subclavian port placement
    - Complications: Arterial puncture (2%), pneumothorax (3.4%)

POST PROCEDURE

Things to Do

- Obtain completion chest x-ray/fluoroscopic image
  - Document catheter position; exclude pneumothorax
- Bed rest
  - Chest port: 1-hour observation; elevate head of bed 15°
  - Arm port: Keep arm in supine position for 1 hour
  - Lumbar port: Bedrest for 4 hours with bed flat
- Watch access site for bleeding or hematoma

Things to Avoid

- Excessively large subcutaneous pocket
  - Port may flip/migrate in large pocket
- Acutely angled tunneled catheter course
  - Catheter may kink/occlude if acutely angled
- Creating venipuncture too high above clavicle
  - Neck movements may cause catheter malposition
- Creating port pocket too low on chest wall
  - Patient's discomfort if port placed close to nipple due to skin sensitivity
  - In obese patients or patients with large breasts, changing from supine to upright position may cause port to move inferiorly with corresponding superior retraction of catheter above SVC
- Creating deep port pocket in obese patients
  - Difficulty with palpating/accessing port
- Manipulation of catheters in setting of thrombosis
  - Inject contrast medium if difficult venous access/difficulty in advancing guidewire
- Intraarterial catheter placement
- Air embolus during catheter placement via sheath
- Catheter damage
  - Suture needle may perforate catheter during venotomy closure
    - Flush port with normal saline/contrast medium
      - Exclude catheter injury before closing pocket

OUTCOMES

Complications

- Immediate/periprocedural complication(s)
  - Hematoma: Most common complication
  - Arterial puncture
  - Pneumothorax: Rare (< 1%)
  - Air embolism
  - Pain at pocket/venotomy site requiring analgesia
  - Access or target vein damage
- Delayed complication(s)
  - Port pocket infection: Overall 3-7%
    - Arm ports (9.9%)
  - Catheter-related sepsis
  - Deep venous thrombosis (DVT): Overall rate is 5-7%
    - Subclavian vein port (5.5%)
    - Internal jugular vein port (2.0%)
    - Arm port (4.5-11.4%)
  - Wound dehiscence/skin necrosis with port exposure
    - Most common in thin/cachectic patients
  - Catheter malfunction 2° to fibrin sheath/thrombus
    - Failure to flush/aspirate
  - Catheter migration
    - May cause port malfunction
  - Catheter rupture or disconnection

Management of Port Catheter-Specific Complications

- Port pocket infection
  - Usually requires port catheter explantation
  - New port catheter can be placed following resolution of infection
- Catheter-related sepsis
  - Requires port catheter removal if proven bacteremia for > 48 hours despite antibiotic treatment
- DVT: Treat with systemic anticoagulation
  - Remove port catheter if DVT advances centrally
- Wound dehiscence/skin necrosis with port exposure
  - Usually requires port removal
- Catheter malfunction
  - Evaluate with radiography for positioning, fluoroscopic digital subtracted contrast injection for physical integrity
  - Ensure access needle located within port
  - Malpositioned catheters
    - May attempt repositioning using fluoroscopy
    - If unsuccessful, port explantation with subsequent new port placement required
  - Catheter rupture or disconnection
    - Remove port; subsequently place new port catheter
  - Catheter malfunction 2° to fibrin sheath/thrombus
    - Inject contrast through port access and obtain venogram using DSA technique to confirm
    - Infuse tissue plasminogen activator: Instill 2 mg into port; aspirate after 30 minutes
    - Fibrin sheath stripping via transfemoral approach

Expected Outcomes

- Port may be used immediately after placement
  - Technical success (100%)
- Procedural complications (5%)
- Long-term complications (8.7%)

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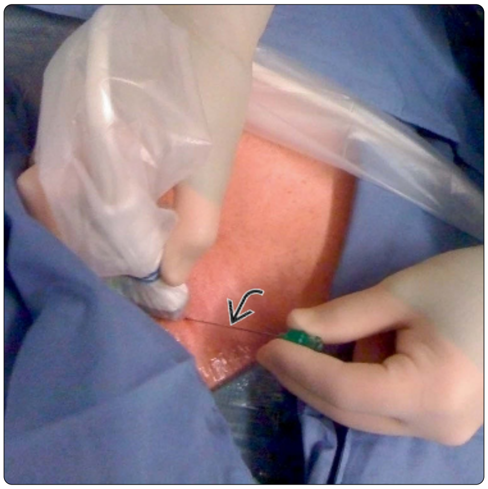
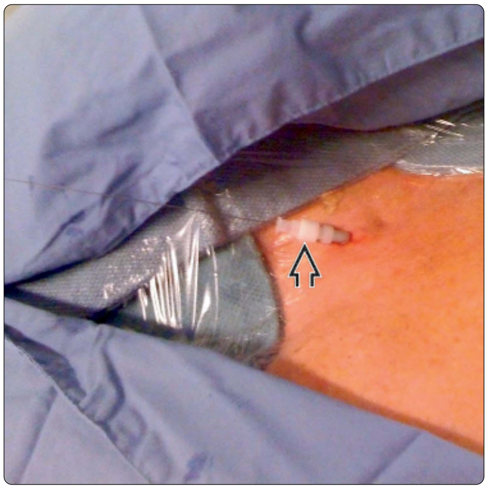
1. Coady K et al: A comparison of infections and complications in central venous catheters in adults with solid tumours. J Vasc Access. 16(1):38-41, 2015
2. Gurkan S et al: Retrospective evaluation of totally implantable venous access port devices: early and late complications. J BUON. 20(1):338-45, 2015
3. Granic M et al: Totally implantable central venous catheters of the port-a-cath type: complications due to its use in the treatment of cancer patients. J BUON. 19(3):842-6, 2014

Chest Port Insertion, Step-by-Step (Initial Venous Access)

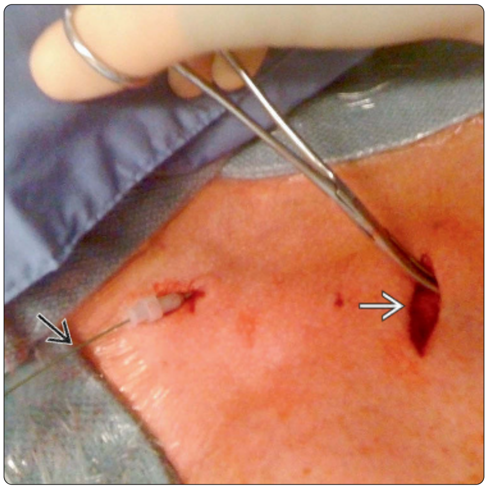


Chest Port Insertion, Step-by-Step (Micropuncture Transitional Dilator)

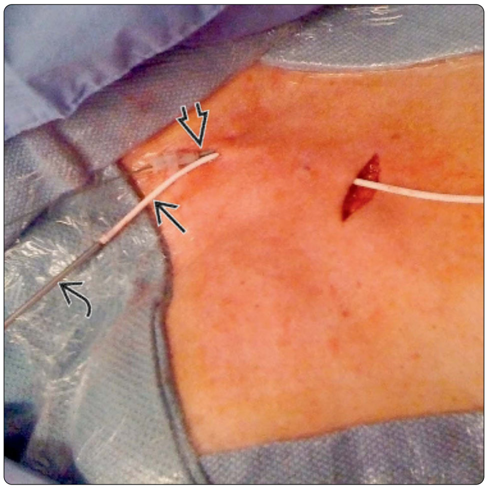


(Left) *After confirming vessel patency, US-guided internal jugular (IJ) vein access is achieved with a 21-gauge micropuncture needle ↷. The needle course shown is parallel to the US probe with the needle entering the vein laterally. A 0.018" guidewire is then introduced through the hub of the micropuncture needle and advanced caudally into the IJ vein using fluoroscopic guidance.* **(Right)** *The micropuncture needle is then exchanged over the microwire for a 5-Fr micropuncture transitional dilator ⇨.*

Chest Port Insertion, Step-by-Step (Subcutaneous Pocket Creation)

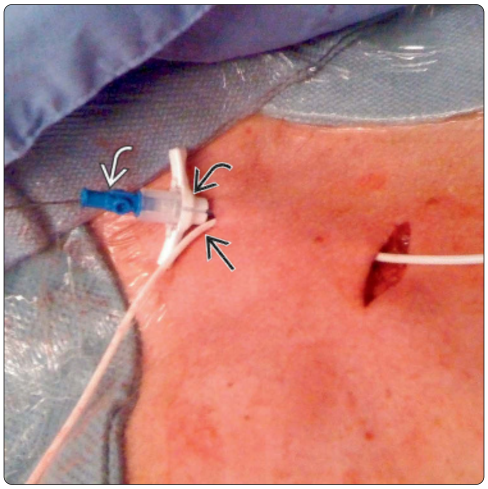


Chest Port Insertion, Step-by-Step (Subcutaneous Tunnel)

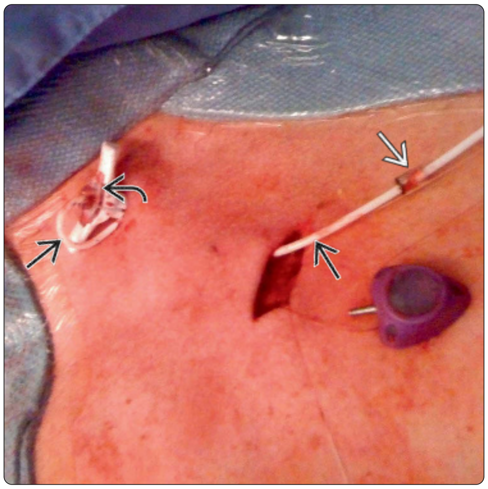


(Left) *The microwire is replaced with an 0.035" guidewire → under fluoroscopic imaging. Then, an incision ➡ of sufficient length to accommodate the port is made in the anterior chest wall, 2-3 fingers width below the clavicle. Blunt dissection with a hemostat creates a subcutaneous pocket just large enough for the port.* **(Right)** *The catheter → is attached to the end of the tunneling device ↷ and advanced from the pocket, through the subcutaneous plane, and out the venotomy site ⇨.*

Chest Port Insertion, Step-by-Step (Peel-Away Sheath Introduction)

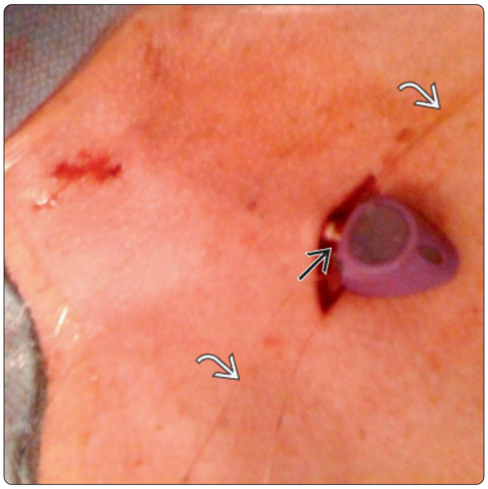


Chest Port Insertion, Step-by-Step (Catheter Placement)

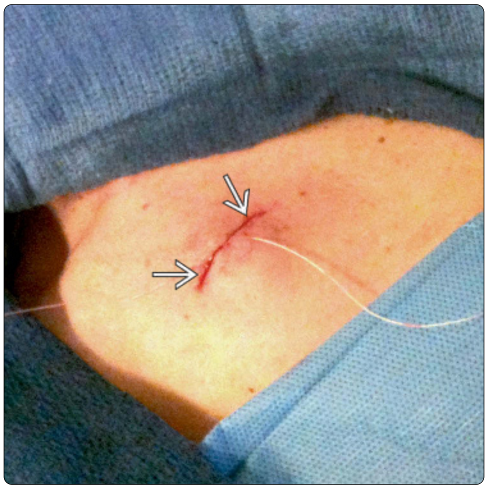


(Left) *Exchange the transitional dilator for a peel-away sheath ↷ and dilator ➥, advanced to the SVC under fluoroscopic guidance. The catheter → should be immediately adjacent to the peel-away sheath with no intervening skin.* **(Right)** *Remove the dilator and guidewire, and manually occlude the sheath hub ↷ if there is no hemostatic valve (prevents air embolus). Introduce the catheter → via the sheath to the atrium. Split and peel away the sheath, leaving the catheter and connector ring ➡ in place.*

(Left) *Position the catheter tip at the cavoatrial junction, and trim the catheter (holding it tightly with fingers). Then, attach the catheter to the port stem ⇨ using the connector. Place the port into the subcutaneous pocket. Optional Vicryl sutures ➦ connecting the port into the pocket may be tied.* **(Right)** *The pocket is typically closed in 2 layers. 4-6 absorbable (3-0) interrupted sutures close deeper subcutaneous tissues. Skin closure ➡ is achieved with an absorbable running subcuticular stitch, or simply with "glue" and Steri-Strips.*

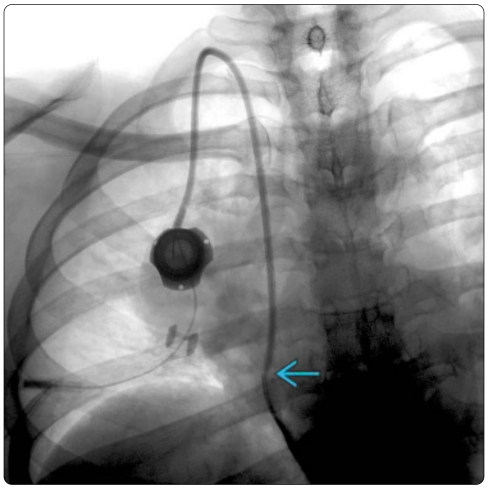


Chest Port Insertion, Step-by-Step (Catheter/Port Attachment)

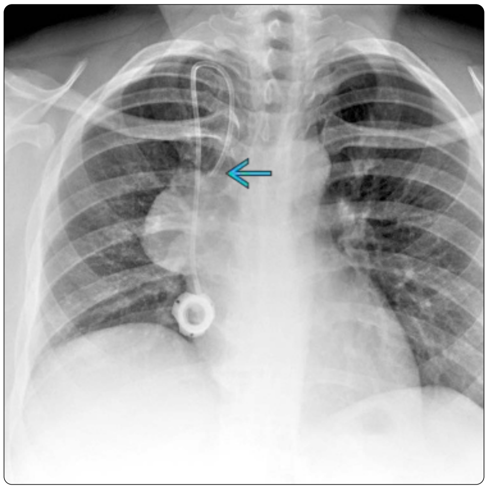


Chest Port Insertion, Step-by-Step (Subcutaneous Pocket Closure)

(Left) *Following port placement, imaging should be obtained to document port position and exclude complications. Port catheter tip location →, however, can change dramatically as seen in this patient imaged supine.* **(Right)** *The same patient is shown standing upright. Especially in obese or large-breasted women, the port is pulled down and the catheter tip → up when the patient is upright. This movement can be minimized by placing the port higher, closer to the clavicle.*

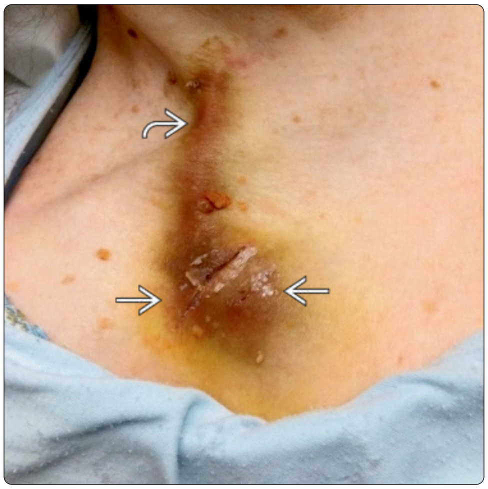


Catheter Tip Position (Patient Supine)

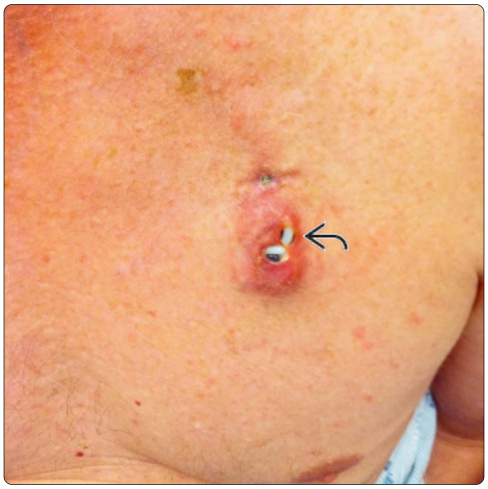


Catheter Tip Position (Patient Upright)

(Left) *A patient on chronic anticoagulation therapy has extensive ecchymosis overlying the port pocket ➡, extending along the subcutaneous catheter tunnel ➦. This resolving hematoma is the most common complication associated with port insertion.* **(Right)** *Erosion of a chest port ↩ through the overlying skin occurred 1 month after insertion. Administration of the angiogenesis inhibitor bevacizumab within 2 weeks before or after insertion increases the risk of this complication.*

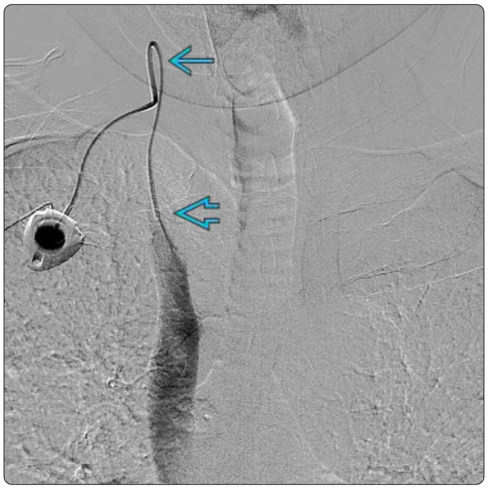


Chest Port Complication (Hematoma)

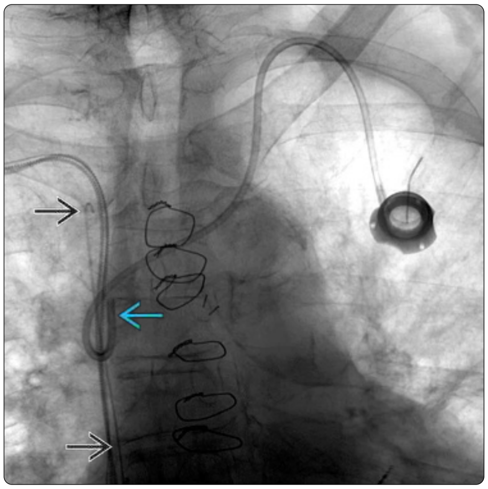


Chest Port Complication (Port Erosion Through Skin)

Complication of Chest Port (High Internal Jugular Access)

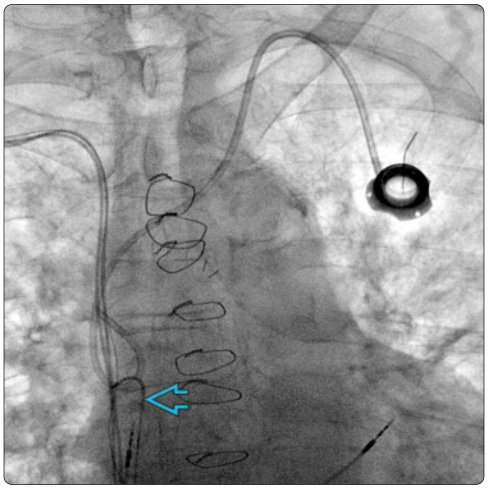


Malpositioned Port Catheter (Initial Position)

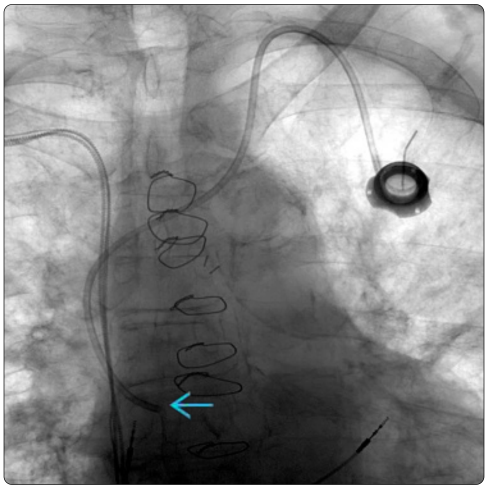


(Left) *Accessing the IJ vein high on the neck may not be problematic. Alternatively, it can cause kinking of the catheter →, or the catheter may flip cranially within the IJ requiring a correctional procedure. In this case, the catheter tip has retracted to the IJ/brachiocephalic vein junction →.* **(Right)** *A malfunctioning left IJ port was found to have a malpositioned catheter pointing superiorly in the SVC →. A RIM catheter → was advanced through the groin to pull the port catheter down.*

Malpositioned Port Catheter (Tip-Deflecting Wire)

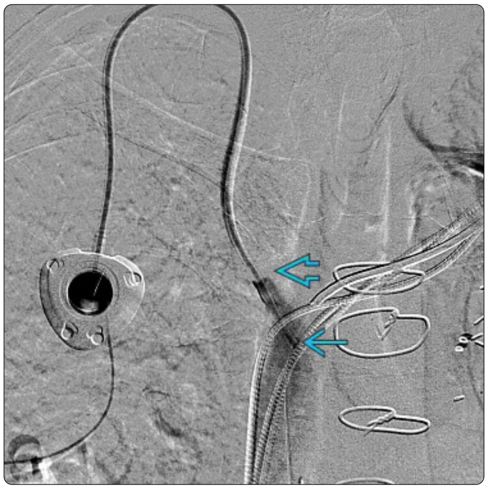


Malpositioned Port Catheter Tip (Final Position)

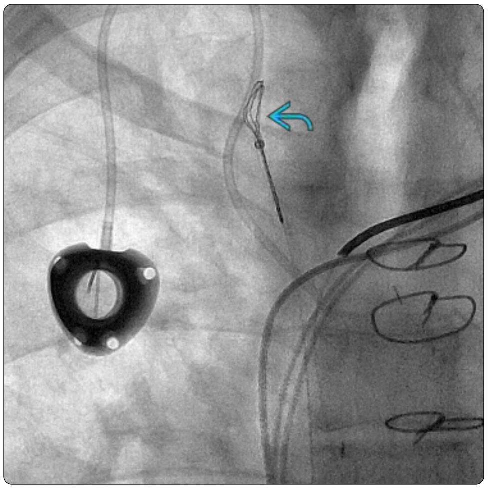


(Left) *The RIM catheter did not have the strength to reposition the catheter, so a tip-deflecting wire → was employed, grabbing the catheter and pulling it to the proper position.* **(Right)** *Final position of the port catheter is acceptable within the right atrium →. No exchange of the left IJ port was necessary.*

Fibrin Sheath Causing Port Malfunction (Diagnostic Port Evaluation)



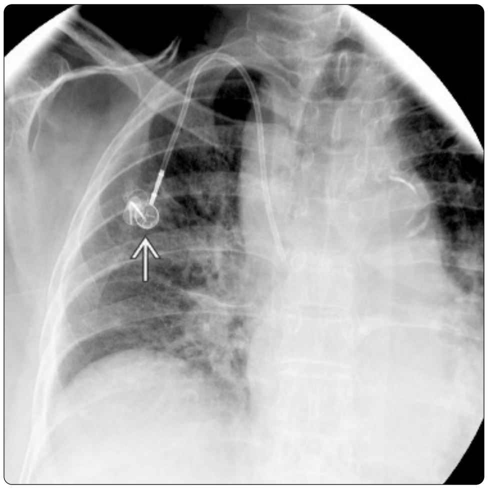
Fibrin Sheath Causing Port Malfunction (Fibrin Stripping)



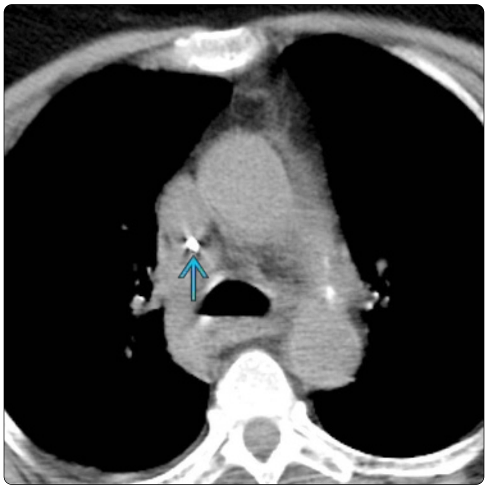
(Left) *Flushing was normal, but aspiration was not possible through this patient's port, a typical history suggesting fibrin sheath. DSA with port contrast-injection shows that contrast does not exit at the tip of the catheter → but instead exits higher at the edge of the fibrin sheath →.* **(Right)** *There are several treatment options when a fibrin sheath is present. The port may be packed with tPA and left to dwell, the port may be exchanged with new IJ access, or a snare → may be used to strip the fibrin off the catheter.*

(Left) *A 76-year-old man complained of pain when injecting through a recently placed port. Fluoroscopic imaging confirms that the Huber needle is well positioned within the reservoir* ➡*. The catheter appeared well positioned in this plane.* **(Right)** *Chest CT was obtained to evaluate port and catheter positioning and to look for underlying vascular issues. At review, it was unclear whether the catheter* ⇨ *was intravascular or posterior to the SVC.*

Extravascular Port Placement (Diagnostic Evaluation)

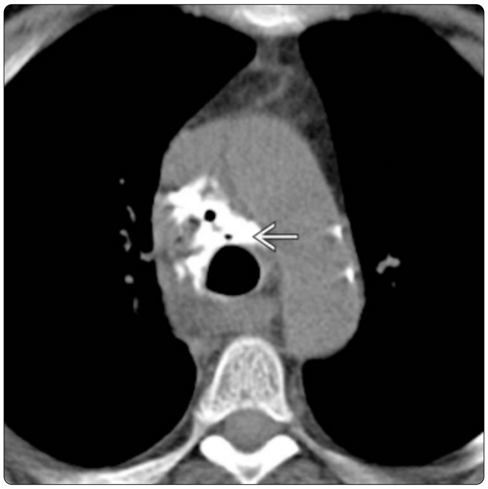


Extravascular Port Placement (Possible Catheter Malpositioning)

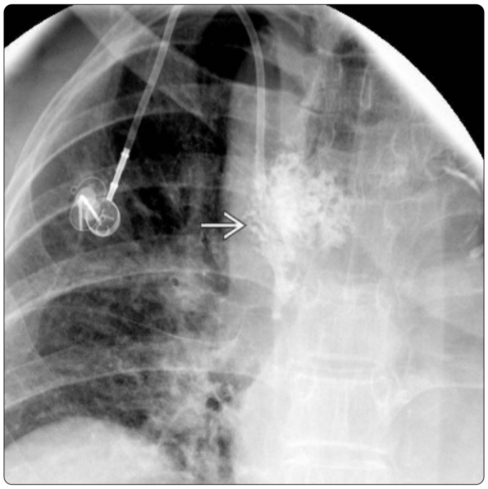


(Left) *Gentle contrast injection through port followed by repeat CT imaging reveals contrast filling mediastinum* ➡*. Undoubtedly, the port had been malpositioned since placement.* **(Right)** *The patient was placed on a fluoroscopy table and prepped for port removal. Contrast pooling within the mediastinum* ➡ *can now be seen fluoroscopically. Ultimately, the catheter was found to enter IJ but then pass through the vessel and exit to the extravascular space where it traversed inferiorly to the mediastinum.*

Extravascular Port Placement (Diagnostic CECT)

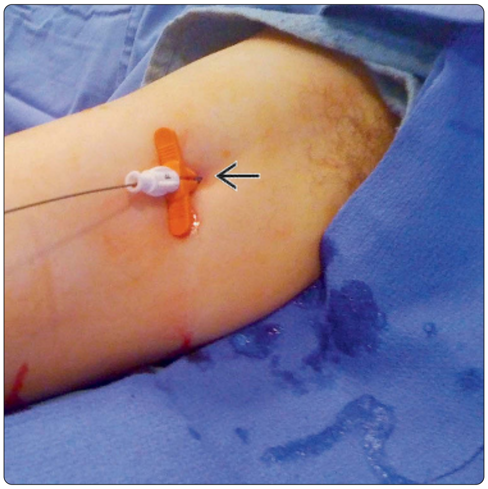


Extravascular Port Placement (Postcontrast Fluoroscopy)

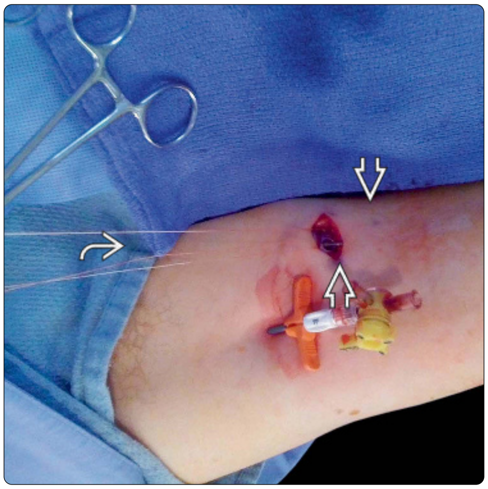


(Left) *US-guided micropuncture access of the brachial vein has been upsized to a 6-Fr peel-away sheath* ⇨ *over an 0.035" guidewire.* **(Right)** *An incision (medial to the access point) is made to the subcutaneous plane, and a port pocket is created using blunt dissection to the level of the muscular fascia plane, just above the biceps* ⇨*. Two (optional) 3-0 Vicryl stay sutures were applied for port reservoir attachment* ➡*.*

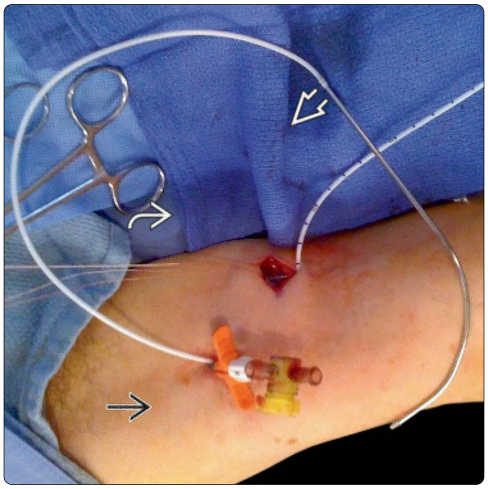
Arm Port Placement, Step-by-Step (Obtain Venous Access)



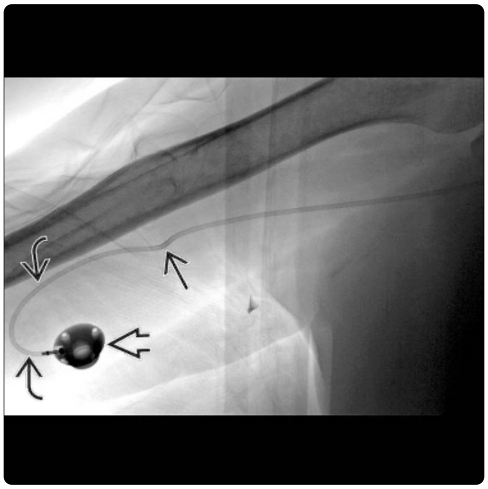
Arm Port Placement, Step-by-Step (Subcutaneous Pocket Creation)



Arm Port Placement, Step-by-Step (Catheter Tunnel and Attachment)

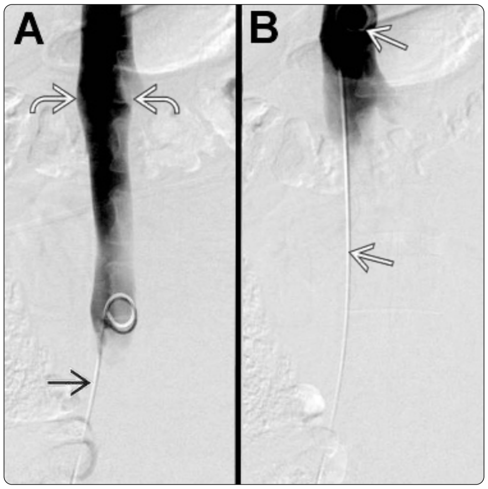


Arm Port Placement, Step-by-Step (Fluoroscopic Imaging)

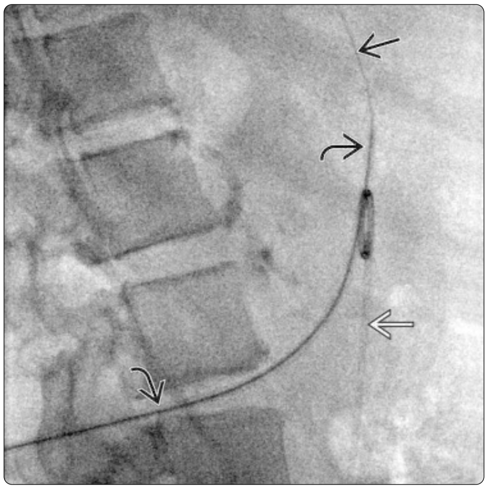


(Left) *The catheter is now tunneled form the port pocket ↪ through the subcutaneous plane to the venotomy site ⇨. The catheter is then detached from the tunneler → and advanced through to the peel-away sheath to the right atrium. The catheter is trimmed and attached to the port, and the pocket is closed.* **(Right)** *Postplacement fluoroscopic spot radiograph shows that the port ⇨ is oriented with the stem directed inferiorly. The catheter has a gentle curve ↪ in the tunnel to the venotomy site →.*

Lumbar Port Placement (Inferior Vena Cavogram)

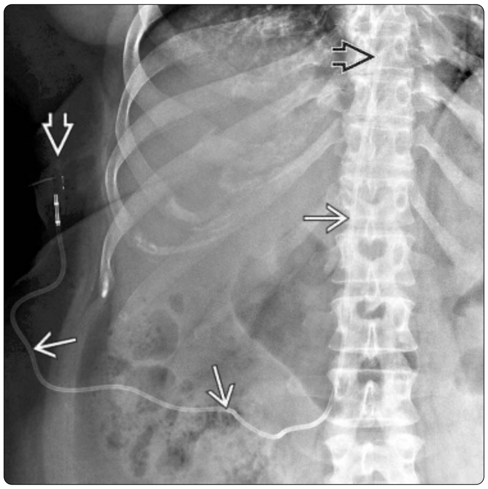


Lumbar Port Placement (Catheter Introduction)

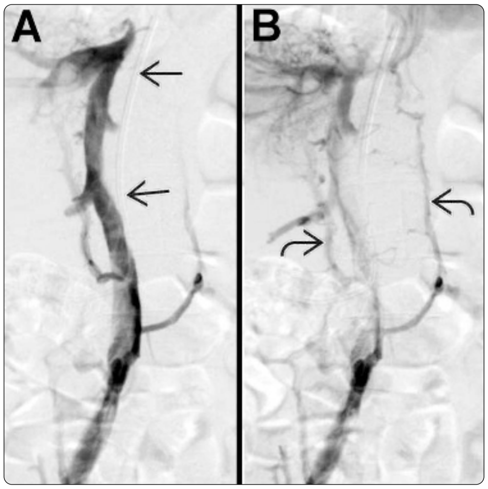


(Left) *(A) Via transfemoral venous access, a pigtail catheter → is placed in the lower IVC, cavography is performed, and the renal veins ↪ identified. (B) The catheter → is advanced to renal vein level and secured at the groin.* **(Right)** *The patient is placed prone, and the right back and flank are prepared and draped. Using the pigtail catheter → as a target, a trocar needle is advanced obliquely through the soft tissues into the IVC. A guidewire → is introduced, and a Neff sheath ↪ advanced into the IVC.*

Lumbar Port Placement (Final Port Position)



Lumbar Port Complication (Partial Inferior Vena Cava Thrombosis)



(Left) *A subcutaneous pocket is created overlying a lower rib or the iliac crest to provide underlying support. The catheter → is tunneled from the pocket to the access sheath, introduced and positioned in the IVC with the tip at the cavoatrial junction ⇨, and attached to the port ⇨.* **(Right)** *Cavogram in a nonfunctioning lumbar port shows (A) the IVC is narrowed and thrombus surrounds the upper part of the catheter →. (B) Delayed image shows venous collaterals ↪. Systemic anticoagulation may restore function.*

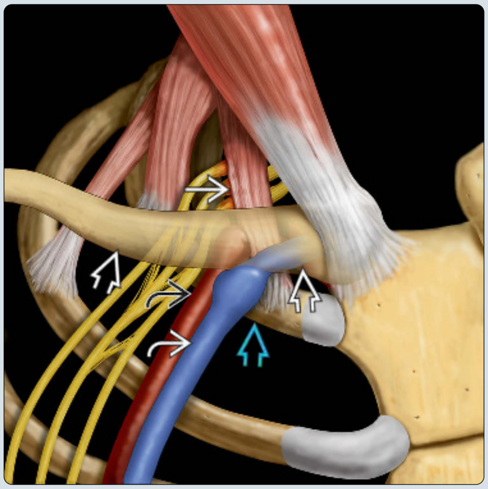
KEY FACTS

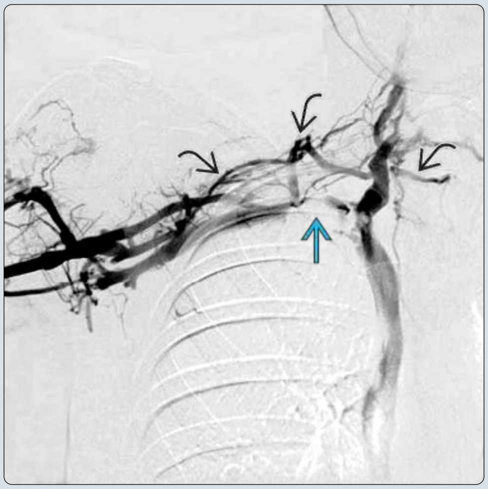
TERMINOLOGY

- **Primary axillosubclavian vein thrombosis (ASVT)**
  - a.k.a. Paget-Schrötter syndrome, effort thrombosis, venous thoracic outlet syndrome
  - Associated with mechanical vein compression
- **Secondary ASVT**
  - Much more common than primary form
  - Central venous catheters/pacemakers primary cause
- **SVC occlusion**
  - Malignant: Lung cancer, lymphoma, malignant etiologies
  - Benign: Catheters, pacemakers, high-flow hemodialysis access

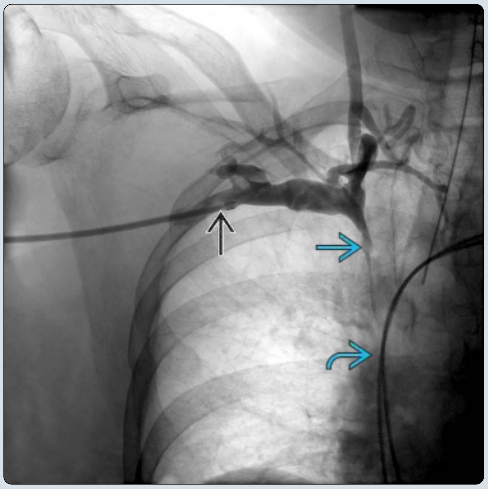
PROCEDURE

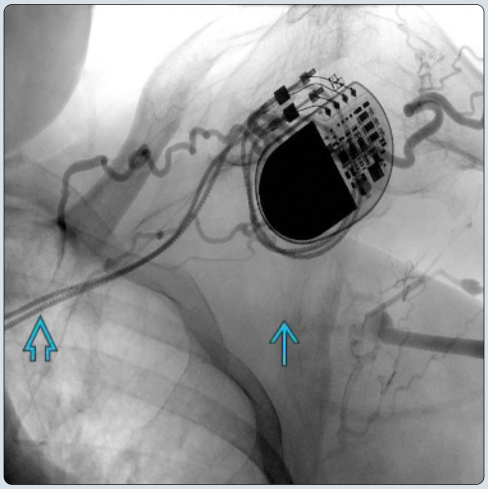
- **Primary ASVT**
  - Best managed by multidisciplinary team of radiologists and surgeons
  - Surgical decompression necessary after successful thrombolysis/thrombectomy
  - Avoid venoplasty prior to surgical decompression
  - Stent contraindicated in thoracic outlet
- **Secondary ASVT**
  - Accounts for 80% of axillosubclavian thrombosis
  - Etiology associated with inciting venous injury from catheters/pacemaker wires
- Angioplasty/stenting indicated for SVC occlusion
  - Covered stent discourages neoplastic invasion
  - May require parallel noncovered stents if brachiocephalic veins involved
  - Poor patency rates for brachiocephalic stents
- **Superior vena cava obstruction**
  - Malignant: Life-threatening requires emergent endovascular stent placement
  - Malignant: Stent-grafts discourage neoplastic invasion
  - Benign: Comparable patency between PTA alone vs. stent at 12 months
  - Benign: Stenting may benefit PTA-resistant lesions


Thoracic Outlet Graphic


Primary Axillosubclavian Vein Thrombosis

(Left) *Graphic shows the characteristic anatomy of the thoracic outlet. The subclavian vein* ↪ *courses anterior to the subclavian artery* ↪*, the anterior scalene muscle* ➔*, and the 1st rib* ⇨*, and is posterior to the clavicle* ➔*.* **(Right)** *DSA venogram shows a filling defect* ⇨ *in the right subclavian vein and extensive collaterals* ↪ *bypassing the occlusion. This young male patient had acute onset of arm swelling, typical of venous thoracic outlet syndrome.*


Central Venous Occlusion


Secondary Axillosubclavian Vein Thrombosis

(Left) *A central venogram was obtained through a long right brachial vein sheath* ⇨ *in this 77-year-old woman requiring new access for hemodialysis. The image shows right brachiocephalic vein stenosis* ⇨ *and superior vena cava (SVC) occlusion* ↪*, which was ultimately recanalized and angioplastied.* **(Right)** *A left upper extremity venogram reveals occlusion of the axillary* ⇨ *and subclavian* ⇨ *veins associated with pacemaker wires.*

Upper Extremity and Central Venous Intervention

TERMINOLOGY

Synonyms

- Brachiocephalic vein = innominate vein
  - Brachiocephalic vein is preferred term
  - Innominate veins bilateral, unlike innominate artery

Definitions

- **Axillosubclavian vein thrombosis (ASVT)**
  - **Primary ASVT**
    - a.k.a. Paget-Schroetter syndrome, effort thrombosis, venous thoracic outlet syndrome
    - Thrombosis/stenosis/occlusion of axillary/subclavian vein
    - Occurs in young adults following repetitive exercises (e.g., swimming, weight-lifting) or prolonged shoulder abduction
      - M:F = 2:1
      - 15-35 years old
      - > 70% of cases involve dominant upper extremity
    - Associated with mechanical vein compression at costoclavicular junction
      - Hypertrophied/broad subclavius or anterior scalene muscle extrinsically compress vein
      - Repetitive trauma leads to thickening and fibrosis
      - Injured venous intima promotes thrombus formation
      - Clavicular and 1st-rib anomalies are rare
    - Clinical symptoms/physical findings
      - Sudden severe unilateral upper extremity swelling resulting from venous hypertension
      - Subocclusive thrombosis and resolution common before ultimate event
      - Prominent collateral veins on arm/shoulder/chest quickly develop on affected side
      - Acute symptoms of heaviness, aching, and swelling improve if ignored/untreated
      - Symptoms return with resumption of activity
      - 10% incidence of pulmonary embolism
  - **Secondary ASVT**
    - Much more common than primary form, accounting for 80% of ASVT
    - Etiology associated with inciting venous injury
      - Long-term central venous catheters/pacemakers primary cause (> 60%); increasing incidence
      - Malignancy/adenopathy (25-29%)
      - Trauma/surgery
      - Radiation therapy
    - May also involve brachiocephalic veins
    - Affected population older and less healthy
- **Superior vena cava obstruction (SVCO)**
  - Malignant etiologies: Most common
    - Responsible for 60-85% of SVCO cases
    - Most common etiologies: Bronchogenic carcinoma, small cell lung cancer, lymphoma, mediastinal metastasis
    - Symptoms typically worse than benign etiologies
      - Rapid onset limiting development of collaterals
      - Central location involving SVC just superior to right atrium, potentially involving azygous vein
  - Benign etiologies: Increasing
    - Most common etiologies
      - Chronic/frequent central venous catheters
      - Transvenous pacemaker wires
      - Fibrosing mediastinitis
  - Superior vena cava syndrome (SVCS)
    - Clinical manifestations of SVCO
      - Neck swelling (100%), facial edema (48-82%), distended neck veins (63%), dyspnea (54-83%), cough (22-58%)
      - Less common is hoarseness, headache, syncope, dizziness, phrenic nerve paresis, chest pain
    - Grade 4 life-threatening SVCS (5% of SVCS presentations)
      - Significant laryngeal edema or cerebral edema, or hemodynamic compromise
      - Requires emergent endovascular stent placement
      - Radiation therapy not indicated for 1st-line treatment if endovascular stenting is feasible
    - If thrombotic etiology (28% of SVCS): Anticoagulation is 1st-line treatment, effective in 88% of cases when started within 5 days
    - If infectious etiology: Antibiotic coverage is 1st-line treatment

Anatomy

- **Venous anatomy of involved veins**
  - Upper extremity deep veins
    - Brachial (usually paired), axillary, subclavian
  - Upper extremity veins
    - Cephalic, basilic, median basilic
      - Basilic vein frequently joins brachial vein
      - Brachial vein terminates in axillary vein
    - Axillary vein starts at border of teres major muscle
      - Becomes subclavian vein at 1st rib outer edge
  - Mediastinal veins
    - Subclavian/internal jugular veins join to form brachiocephalic veins
    - Brachiocephalic veins join to form SVC
      - SVC posterior to manubrium/sternum on right
    - Collateral drainage with chronic SVC occlusion
      - Azygos system; unnamed neck/chest collaterals
- DSA minimizes required volume of contrast media

PREPROCEDURE

Indications

- **Primary ASVT**
  - Acute swelling and pain, phlegmasia caerulea dolens in most extreme cases
  - Postphlebitic limb reported in up to 44%
  - Chronic pain, sensory loss, vocational disability
- **Secondary ASVT**
  - Symptomatic obstruction
  - Decreased hemodialysis access flow parameters
- **SVCO**
  - Symptomatic malignant or benign occlusions
  - Restore central venous patency for hemodialysis access

Contraindications

- Severe heart failure: Upper extremity venous reperfusion may cause pulmonary edema

- Bacteremia/sepsis: Should not place covered stent
- Risk factors for thrombolytic agent administration

Preprocedure Imaging

- **US**
  - Screening modality for identifying/characterizing upper extremity venous disease
    - Upper arm veins/ASVT
      - Evocative maneuvers increase accuracy
    - Visible thrombus/venous noncompressibility diagnostic of thrombosis
    - Venous compressibility excludes thrombosis
      - May mistake dilated collateral for normal vein
  - Cannot reliably evaluate brachiocephalic veins/SVC
    - Anatomy prevents adequate US "window"
    - Absence of normal atrial waveform/respiratory phasicity suggests obstruction/thrombosis
      - Low-velocity/monophasic antegrade flow
    - Distended jugular/subclavian veins suggestive of central occlusion
- **Computed tomography venography (CTV)**
  - Suggested brachiocephalic/SVC CTV protocol
    - Piggyback contrast injection technique
      - 1st: 100 mL contrast at rate of 4 mL/s
      - 2nd: 80 mL saline/20 mL contrast at 3 mL/s
      - Obtain images at 65- to 90-s delay
  - Standard contrast injection with venous delay often results in nonuniform venous enhancement
  - CECT/CTV findings
    - Thrombus seen as very low-density filling defect
    - Contrast flows around thrombus periphery
      - Outlines thrombus as tram-track sign
    - Dilated vein, extensive collaterals
    - Postthrombotic changes in chronic DVT
      - Severe venous narrowing/barely visible lumen
      - Eccentric linear filling defect(s)
      - Occasional calcification
    - SVC stenosis/occlusion
      - Tumor mass may be present
      - Absent or narrowed SVC
      - Intraluminal filling defects
      - Prominent azygos arch and vein
- **Magnetic resonance venography (MRV)**
  - Useful in setting of contrast allergy
  - T1WI: Acute thrombus may appear as high signal
  - T2WI: Bright blood SSFP shows low-signal thrombus
    - SSFP imaging provides dynamic flow information
  - TR-MRA mimics contrast venogram, shows absent contrast opacification and collateral flow pattern
  - Improved noncontrast sequences now available
  - Combine with CT in evaluation of ASVT to identify site/cause of mechanical venous obstruction
- **Venography**
  - Gold standard for interventional planning
  - Imaging guidance for intervention
  - If no stenosis/obstruction on venogram, consider evocative maneuvers during venography to reproduce functional obstruction
    - Evocative maneuver places arm in position that reproduces patient's symptoms

Special Considerations

- **Primary ASVT**
  - Best managed by multidisciplinary team of radiologists and surgeons
  - Avoid venoplasty prior to surgical decompression
  - Treatment guidelines (Exeter protocol)
    - Select appropriate patients (young, dominant arm, short duration, athletic)
    - Endovascular thrombolysis [0.5-1.0 mg tissue plasminogen activator (tPA)], IV heparin and aspirin
      - No venoplasty
    - Follow with surgical resection and vein release
    - Aspirin or warfarin for 3 months after surgical release
    - Perform venogram and potential venoplasty 2-3 weeks after surgical release
    - Return to activity after 4-6 weeks
- **Central venous stenosis in hemodialysis patients**
  - Affect 25-40% of hemodialysis patients
  - May present as high recirculation rates or prolonged bleed at hemodialysis
  - Management involves repeated endovascular interventions
  - Do not compromise future hemodialysis access sites with intervention

Getting Started

- Things to check
  - History and physical examination
    - Clinical history
      - Etiology of obstruction (malignant/benign)
      - History of radiation/chemotherapy/central catheters/pacemaker/decreased hemodialysis access sites
      - Prior endovascular or surgical interventions
      - Contraindication to thrombolytics
    - Physical examination
      - Evidence of central venous obstruction
      - If clinical signs of heart failure present, obtain echocardiogram to determine ejection fraction
    - Review current medications, specifically anticoagulants or antiplatelet agents
  - Consent
    - At minimum, discuss potential injury to target veins or adjacent vascular/nonvascular structures, inability to cross stenosis/occlusion, contrast-induced nephropathy, infection, pericardial tamponade, and mediastinal hemorrhage (SVCO), death
  - Allergies
    - Premedicate if necessary
  - Hemostatic risk of procedure
    - Diagnostic angiography = low risk of bleeding
      - INR recommended if receiving warfarin or liver disease
      - Platelet, hematocrit, aPTT: Not routinely recommended
    - Venous intervention = moderate risk of bleeding
      - INR recommended
      - aPTT recommended if receiving IV heparin
      - Platelet, hematocrit: Not routinely recommended
  - Laboratory parameters

    - Electrolytes, glomerular filtration rate (eGFR)
      - ☐ Prefer normal Cr; eGFR > 60
    - Complete blood count
      - ☐ Platelet count > 50,000/µL
    - Coagulation profile
      - ☐ INR ≤ 1.5
      - ☐ Normal prothrombin time, partial thromboplastin time
  - Preprocedural planning
    - Review all pertinent available imaging
  - Periprocedural planning
    - Inpatient bed available to monitor thrombolysis
    - Hemodialysis schedule if chronic renal failure
    - Anticoagulation management
- Medications
  - Sedative/analgesic agents
    - Venous angioplasty may be extremely painful
    - Stent placement may also illicit transient pain
    - General anesthesia may be necessary for complex central venous recanalization
  - Antithrombotics
    - Heparin, 2,000-5,000 IV prior to crossing lesion
    - Thrombolytics, administered locally through catheter placed within or very near thrombus
      - ☐ tPA (alteplase), 0.5-1.0 mg/hr
      - ☐ Recombinant tissue plasminogen activator [(rPA) reteplase; tenecteplase]
      - ☐ Urokinase
    - Low molecular weight heparin, bridge from preprocedure and to postprocedure warfarin therapy
  - Prophylactic antibiotics
    - Procedure: Clean
    - Organisms encountered: *Staphylococcus aureus* and epidermidis
    - Diagnostic angiography, percutaneous angioplasty (PTA) = no antibiotics recommended
    - Endovascular stent (bare metal stent) placement
      - ☐ Routine placement = no antibiotics recommended
      - ☐ High risk patients (repeat intervention within 7 days, prolonged duration of procedure) may receive antibiotics
      - ☐ 1 g cefazolin
      - ☐ Vancomycin or clindamycin if penicillin-allergic
    - Stent graft placement, including hemodialysis access endografts
      - ☐ Antibiotics recommended
      - ☐ 1 g cefazolin
      - ☐ Vancomycin or clindamycin if penicillin-allergic
- Equipment list
  - Micropuncture set for venous access
  - Guidewires
    - 0.035" starter guidewire
    - Angled or straight-tipped hydrophilic guidewire
      - ☐ Used for crossing lesion
    - Stiff guidewire (e.g., Amplatz, Rosen, Lunderquist)
      - ☐ Gives stability for angioplasty or stent placement
  - Catheters/sheaths
    - Vascular access sheath
    - Selective catheter(s)
      - ☐ Directional catheter (e.g., Kumpe/Berenstein)
    - Flush catheter(s)
      - ☐ Pigtail/Omni Flush
  - Angioplasty (PTA) balloon catheter
    - Diameter/length based on target lesion
    - High-pressure balloon usually required
    - Scoring/cutting balloon for resistant lesions
  - Mechanical/pharmacologic thrombolysis equipment
    - Possis AngioJet (Medrad; Warrendale, PA)
    - ThromCat system (Kensey Nash; Exton, PA)
    - Trellis system (Bacchus Vascular; Santa Clara, CA)
    - EkoSonic catheter system (Ekos; Bothell, WA)
  - Stents
    - Self-expanding, noncovered, bare metal stent
      - ☐ Wallstent (Boston Scientific; Natick, MA)
      - ☐ Protégé GPS (Covidien; Mansfield, MA)
    - Self-expanding, covered
      - ☐ Fluency endovascular stent (Bard; Tempe, AZ)
      - ☐ Viabahn endoprosthesis (Gore; Flagstaff, AZ)

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Axillosubclavian lesion
    - Brachial vein access
      - ☐ May occasionally also require femoral access
  - Brachiocephalic vein lesion
    - Brachial/axillary approach
      - ☐ May occasionally also require femoral access
      - ☐ May occasionally require bilateral axillary approach ("floss" technique)
  - SVC lesion
    - May require combined approach
      - ☐ May include femoral/brachial/internal jugular

Procedure Steps

- **Procedure-specific goals**
  - Localize stenosis/occlusion, determine best route to access for treatment
  - Evaluate potential thrombus and need for thrombolysis/systemic anticoagulation
  - If appropriate, recanalize vessel and restore patency
- **General**
  - Obtain venous access with US guidance
  - Introduce vascular access sheath
    - May perform DSA venogram via sheath
      - ☐ May perform DSA venogram via catheter instead
  - Introduce appropriate diagnostic catheter
  - Selectively catheterize target vein
  - Position catheter proximal to stenosis/thrombosis
    - Obtain DSA; define anatomy of stenosis/occlusion
      - ☐ Anatomy determines PTA vs. thrombolysis
      - ☐ Lengthy occlusion may need thrombolysis
  - Advance guidewire across stenosis/thrombosis
    - Hydrophilic guidewire optimal for crossing lesion
    - Once guidewire central to lesion exchange for nonhydrophilic sturdy wire (e.g., Amplatz)
  - Perform angioplasty &/or thrombolysis
- **Axillosubclavian vein stenosis/thrombosis (conservative management)**

- If catheter related, consider removal
  - Must consider medical necessity of catheter
    - Removal may be contraindicated if continued access needed and no other available access site
  - Anticoagulation may give rapid symptom relief
    - Institute ± catheter removal
    - Decreases clot propagation, facilitates collaterals
    - 6-month anticoagulation course is typical
- **Axillosubclavian vein stenosis/thrombosis (interventional management)**
  - **Angioplasty**
    - Short, well-defined segmental occlusion/stenosis
      - High-pressure balloon may be required
      - Avoid venoplasty prior to surgical decompression in primary ASVT
    - Stents usually contraindicated in thoracic outlet
      - High stent fracture rate; compression by adjacent musculoskeletal structures
      - Poor long-term patency
      - If absolutely needed, consider flexible covered stent; cannot cover inflow veins
  - **Catheter-directed thrombolysis (CDT)**
    - May be needed for lengthy occlusions
      - Effective in relatively acute thrombosis
    - May precede CDT with mechanical thrombolysis
      - Initial debulking of thrombus
      - Use CDT to lyse any residual thrombus
    - May also use CDT as stand-alone therapy
    - Use multiple sidehole/Ekos infusion catheter
      - Catheter should traverse thrombus; maximal concentration of thrombolytic agent
      - Match infusion length of catheter with thrombosed segment length
    - May administer bolus of thrombolytic agent
    - Continuous infusion therapy for several hours
      - Typical infusion: tPA 0.5-1.0 mg/h
    - Track fibrinogen and repeat venography at intervals to assess progress
    - May need additional interventions after CDT
      - Angioplasty/thrombectomy
  - **Mechanical/pharmacomechanical thrombolysis**
    - Useful for lengthy occlusions
      - Effective with chronic occlusion/thrombosis
    - Shorter treatment times compared with CDT
      - Treatment times of 60-90 minutes
      - May require multiple passes with device
    - Highly effective for clot burden removal
      - May be used to debulk thrombus
      - May use in combination with CDT if needed
    - Various device choices (e.g., AngioJet, Cleaner)
  - **Surgery**
    - 1st-rib resection necessary after successful thrombolysis/thrombectomy in primary ASVT
      - Must relieve mechanical compression of vein
      - Significantly improves long-term patency
      - Stent may be used after rib resection if needed
      - May also perform vein patch angioplasty
    - Delay in rib resection after thrombolysis/thrombectomy may result in venous reocclusion
    - Some studies show thrombolysis before resection unnecessary; advocate anticoagulation only
- **SVC stenosis/occlusion**
  - May need jugular/upper extremity (superior) and femoral (inferior) access to cross lesion
  - Extensive SVC thrombosis may require thrombolysis
    - CDT preferred over mechanical thrombolysis
  - Malignant SVCO
    - Stent is 1st-line treatment, favored over PTA alone
    - Requires large-diameter stent (e.g., Wallstent)
    - Covered stent discourages neoplastic invasion
      - Must not cover inflow venous tributaries
      - Covered stent diameter may be inadequate to treat SVC
  - National Kidney Foundation-Kidney Disease Outcomes Quality Initiative (NKF-KDOQI) treatment guidelines of benign SVCO of hemodialysis
    - Place stent for immediate recoil of stenosis after PTA
    - Place stent for residual 30% stenosis after PTA
    - Place stent for lesions recurring within 3 months of PTA
  - If occlusion involves brachiocephalic veins
    - May require parallel noncovered stents
      - Extend from brachiocephalic veins into SVC
      - Poor patency rates for brachiocephalic stents
- **Advanced techniques to recanalize central venous occlusion**
  - Ensure appropriate level of experience and training, plus risk/benefit of each case
  - Review all recent cross-sectional imaging
    - Understand pathway of occluded target vein
    - Relationship to potentially problematic adjacent structures and vessels
    - Relationship of occluded vein to superior extent of pericardium
  - Advance rigid sheath (7- to 8-Fr, radiodense tip) to within 1-2 cm of obstruction
  - Advance 3- to 5-Fr catheter (e.g., Quick-Cross, Spectranetics; Colorado Springs, CO) to obstruction
  - Gently inject contrast in multiple fluoroscopic projections to confirm wire trajectory
  - Consider positioning intravascular snare opposite occlusion to act as target and to grab wire
  - Advance 1-2 cm through occlusion
    - Alternate hydrophilic wires (Glidewire, Roadrunner, Advantage)
    - Alternate hydrophilic and nonhydrophilic stiff wires (Amplatz)
    - Alternate use of hydrophilic/diagnostic, straight/angled catheters
    - Employ use of microwires and microcatheters through 3- to 5-Fr catheter
    - Consider firmly advancing through fibrinous occlusion with back of wire
    - Consider sharp recanalization with transjugular intrahepatic portosystemic shunt (TIPS) needle, or similar-type needle
    - Consider heated-tip radiofrequency wire (Baylis Medical Company Inc.; Montreal, Canada)
  - Inject contrast after advancing each 1-2 cm to ensure intraluminal position

Alternative Procedures/Therapies

- Surgical
  - Venous bypass/venous transposition
- Other
  - SVCO (malignant)
    - External beam radiation &/or chemotherapy

POST PROCEDURE

Things to Do

- If treatment using CDT
  - Monitor fibrinogen levels
    - Should be kept above 100 mg/dL
      - Low levels increase bleeding complication rate
    - If fibrinogen level < 100 mg/dL
      - Decrease thrombolytic agent dose/stop infusion
- 3-6 months warfarin anticoagulation after intervention
  - Indicated after ASVT
  - No definite benefit after SVC stent

OUTCOMES

Complications

- Most feared complication(s)
  - Complications related to thrombolysis
    - Hemorrhagic complications (0-17% incidence)
      - Intracranial/retroperitoneal/GI hemorrhage
  - Pulmonary embolus (< 1% incidence)
  - Venous perforation
    - May occur with aggressive SVC angioplasty
      - Possible pericardial tamponade if SVC rupture
  - SVC stent migration/embolization to heart
- Immediate/periprocedural complication(s)
  - Complications of gaining venous access
    - Bleeding/hematoma/nerve injury
  - Acute thrombosis of SVC stent
- Delayed complication(s)
  - Occlusion of SVC stent
    - Neointimal proliferation (benign disease)
    - Neoplasm ingrowth (noncovered > covered stent)
  - Bare metal stent associated with neointimal hyperplasia, fracture, migration, shortening

Expected Outcome

- ASVT
  - High initial technical success rate for thrombolysis
- Malignant SVC obstruction
  - Symptomatic relief achieved in 68-100%
    - Relief almost immediate with successful stenting
- Benign SVC obstruction
  - Repeated interventions are necessary to maintain patency
  - Comparable patency between PTA alone vs. stent at 12 months
    - 1 study found superior patency for PTA alone vs. stent but similar secondary patency
  - Placing stent may benefit PTA-resistant lesions
  - Patency rates of stents used to treat SVC obstruction
    - Primary patency
      - 6 months = 46-84%
      - 12 months = 20-56%
    - Secondary patency
      - 6 months = 76-97%
      - 12 months = 20-56%
    - Nitinol-shape memory alloy stents have higher primary patency than steel stents
    - Stent-grafts reduce restenosis rates with promising medium-term results
      - 39-100% primary patency at 12 months
      - 80-100% cumulative patency at 9-12 months
      - Risk covering and occluding collateral veins
    - Difficult to compare studies performed with stents of differing construction and materials

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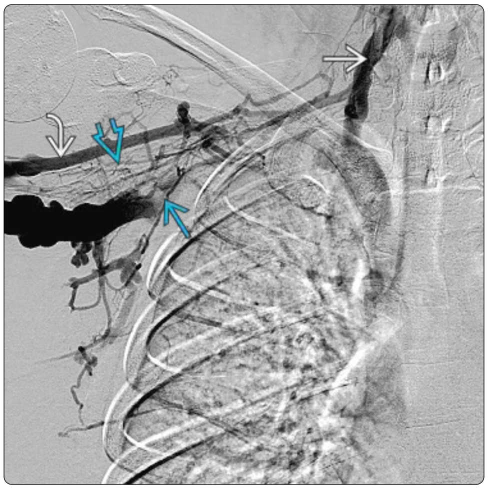
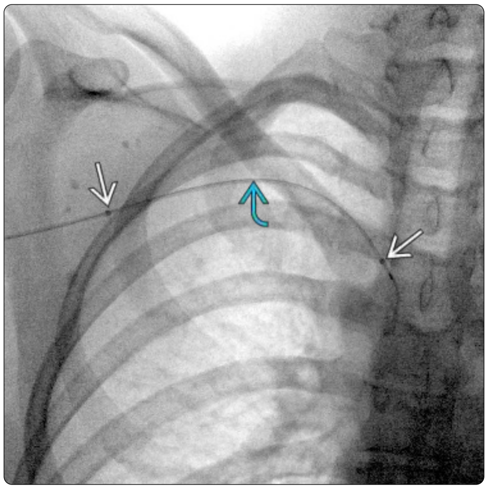
(Left) *Left upper extremity DSA venogram reveals intraluminal thrombus* → *occluding the axillary and subclavian veins, with collateral veins* → *bypassing the occluded segments. The cephalic* ➔ *and internal jugular* ➔ *veins remain patent.* **(Right)** *Catheter-directed thrombolysis (CDT) was performed through an infusion catheter positioned within the axillary and subclavian veins* →*, with tissue plasminogen activator (tPA) delivered between the 2 radiodense markers* ➔*.*

Primary Axillosubclavian Vein Thrombosis (Diagnostic Venogram)

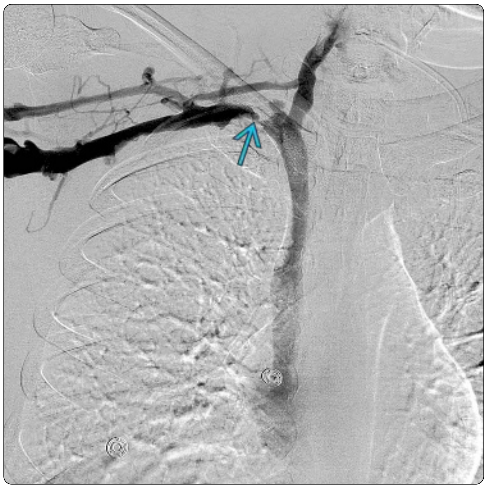


Primary Axillosubclavian Vein Thrombosis (Catheter-Directed Thrombolysis)

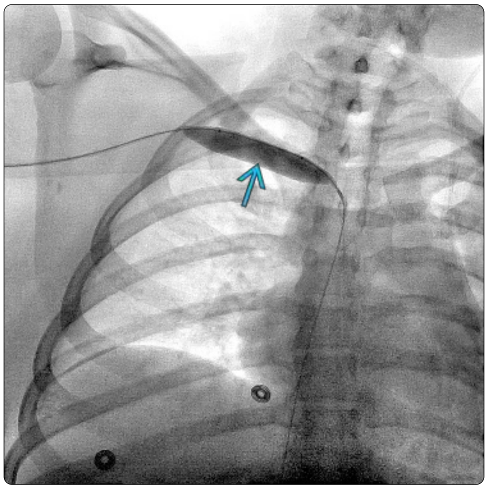


(Left) *Thrombus resolved following overnight CDT. Subsequent right upper extremity and central venous DSA venography revealed underlying high-grade stenosis of the subclavian vein* →*.* **(Right)** *Rather than undergoing surgical release (the recommended treatment), percutaneous angioplasty (PTA) of the stenosis was performed* → *without surgical intervention.*

Primary Axillosubclavian Vein Thrombosis (Underlying Venous Stenosis)

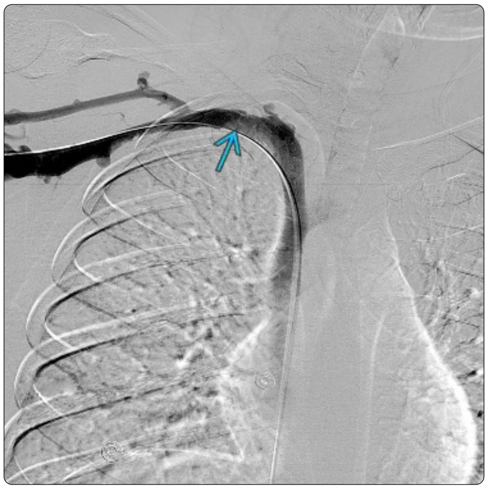


Primary Axillosubclavian Vein Thrombosis (Angioplasty)

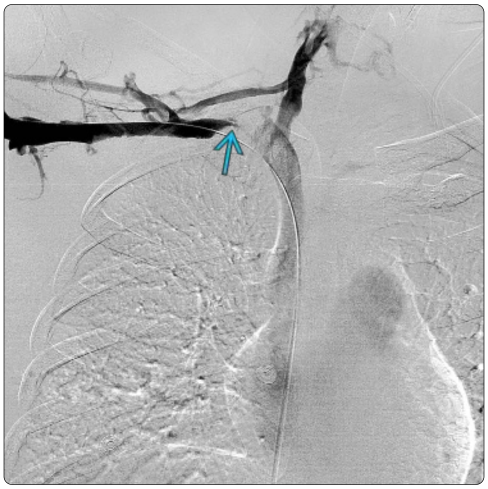


(Left) *Following PTA, the stenosis appears resolved* → *with moderate abduction.* **(Right)** *However, exaggerated abduction of the arm reveals continued extrinsic compression of the subclavian vein* →*, consistent with persistent primary axillosubclavian vein thrombosis that is at this time unresolved and likely to result in repeated thrombus formation.*

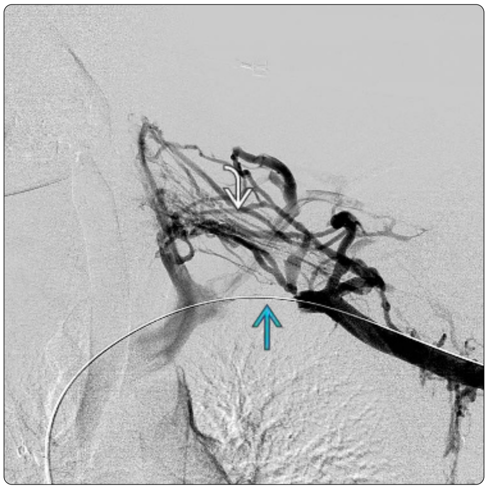
Primary Axillosubclavian Vein Thrombosis (Apparent Resolution of Stenosis)



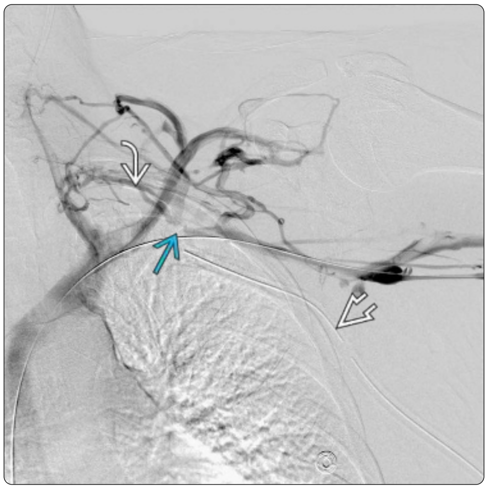
Primary Axillosubclavian Vein Thrombosis (Extrinsic Compression Remains)



Primary Axillosubclavian Vein Thrombosis (Diagnostic Venogram)

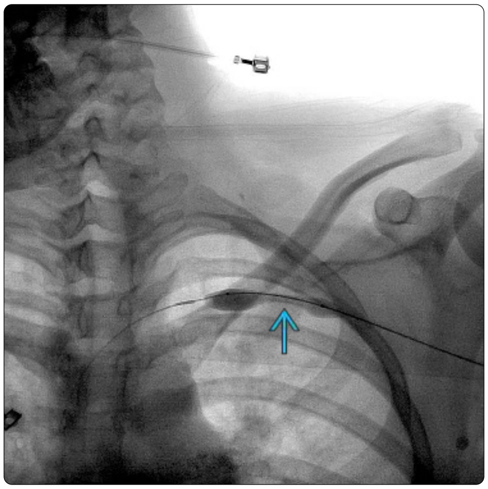


Primary Axillosubclavian Vein Thrombosis (Post Thrombolysis and Resection)

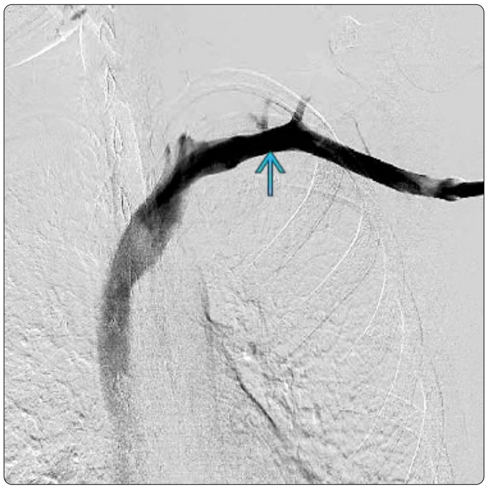


(Left) *DSA venogram in an 18-year-old swimmer with acute arm swelling reveals total occlusion of the subclavian vein* → *due to extrinsic compression by a hypertrophied middle scalene muscle. Well-formed collaterals* ➦ *allow venous drainage around the occlusion.* **(Right)** *Following endovascular thrombolysis and surgical resection of the 1st rib, a repeat venogram revealed residual subclavian vein stenosis* → *and continued filling of collateral veins* ➦*. A postoperative subcutaneous drain is present* ⇨*.*

Primary Axillosubclavian Vein Thrombosis (Angioplasty)

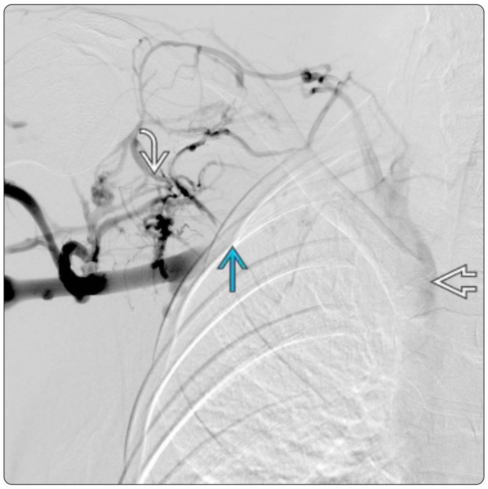


Primary Axillosubclavian Vein Thrombosis (Resolution of Stenosis)

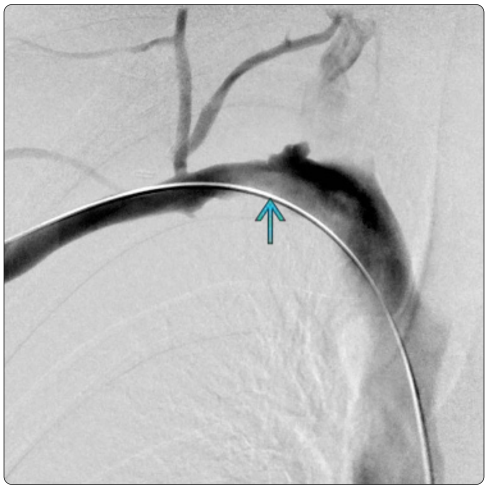


(Left) *PTA was performed 2 weeks after surgical release of the hypertrophied middle scalene muscle. "Waisting" of the angioplasty balloon* → *confirms underlying stricture of the vessel.* **(Right)** *Following thrombolysis, surgical decompression, and PTA, ASVT has resolved* →*. The vessel is now of normal caliber on this final DSA venogram and remained noncompressed in both abduction and adduction.*

Primary Axillosubclavian Vein Thrombosis (Diagnostic Venogram)



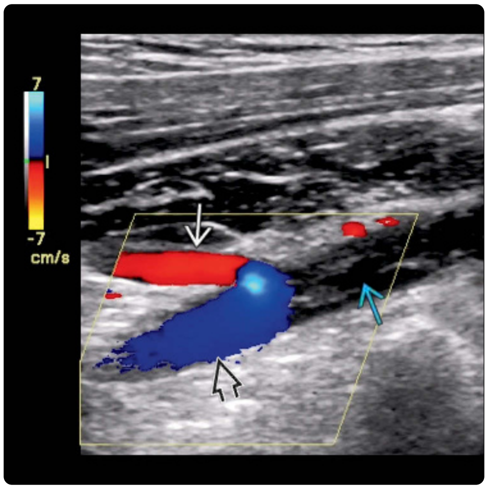
Primary Axillosubclavian Vein Thrombosis (Resolution of Stenosis)



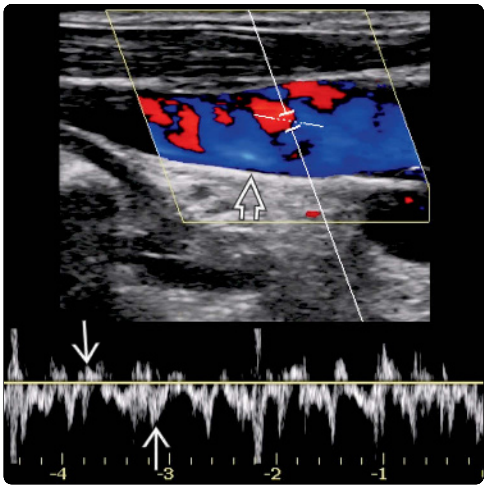
(Left) *A similar DSA venogram with axillosubclavian occlusion* → *and filling of collateral veins* ➦ *is apparent in this 23-year-old baseball pitcher. Note patency of the brachiocephalic vein* ⇨*.* **(Right)** *DSA venogram following thrombolysis, surgical decompression, and PTA reveals no residual underlying axillosubclavian vein stricture or flow restriction* →*.*

(Left) *Sagittal color Doppler US shows a patent right axillary vein ⇨ with no color flow in the subclavian vein ⇨ distal to the cephalic vein ➡. The latter vein shows reversal of flow as indicated by the color assignment. The findings are consistent with right subclavian venous thrombotic occlusion.* **(Right)** *Sagittal color Doppler US of the right internal jugular vein shows color flow in a patent vein ➡. Doppler waveform analysis shows a normal atrial waveform and respiratory phasicity ➡, which indicates a patent SVC.*

Primary Axillosubclavian Vein Thrombosis (Ultrasound Evaluation/Diagnosis)

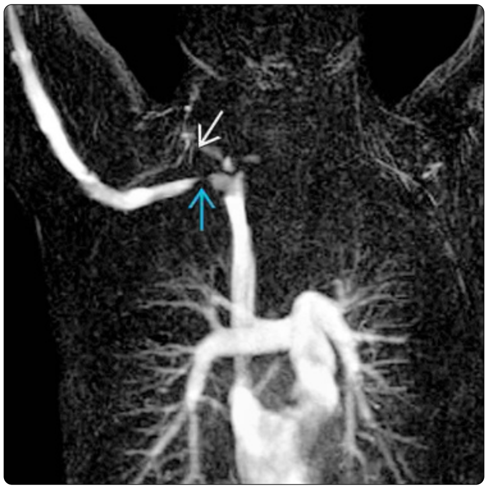


Primary Axillosubclavian Vein Thrombosis (Ultrasound Evaluation/Diagnosis)

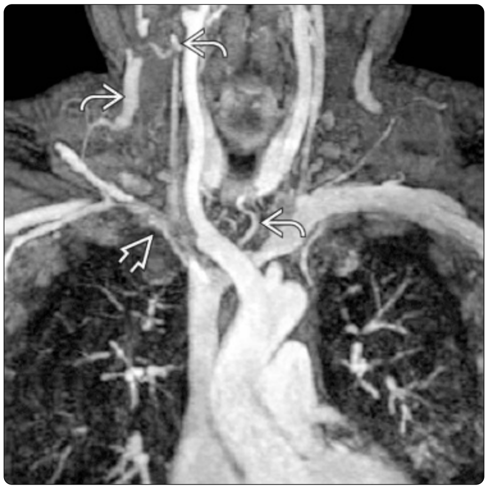


(Left) *Coronal MRV obtained with both arms raised shows marked focal narrowing of the right subclavian vein ⇨ without thrombus. Collaterals ➡ bypass the compressed venous segment.* **(Right)** *Coronal MRV in a different patient shows that the right subclavian vein ➡ is thrombosed, and there are fairly prominent venous collaterals ➡ present. The arm pain and swelling that occurs with acute thrombosis usually improves as venous collaterals quickly develop.*

Primary Axillosubclavian Vein Thrombosis (MRV Evaluation/Diagnosis)

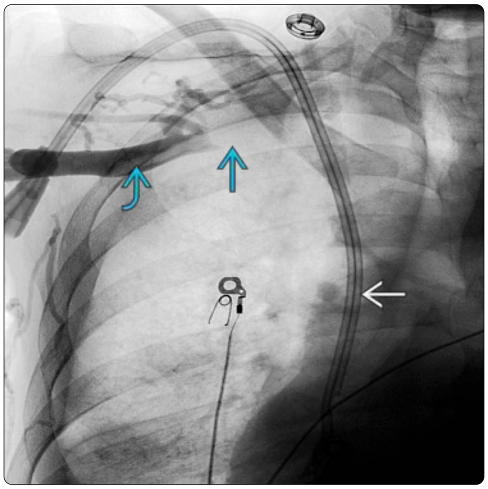


Primary Axillosubclavian Vein Thrombosis (MRV Evaluation/Diagnosis)

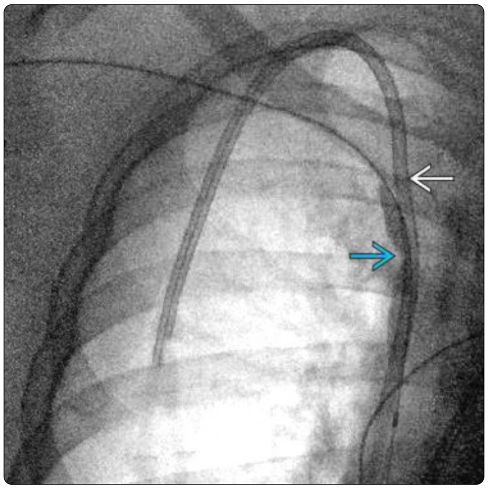


(Left) *A venogram in a patient with right arm swelling reveals occlusion of the subclavian vein ⇨ with acute thrombus extending into the axillary vein ⇨. The presence of a hemodialysis catheter ➡ suggests iatrogenic cause, i.e., secondary ASVT.* **(Right)** *A different patient with similar right arm swelling was found to have right brachiocephalic vein stenosis related to her hemodialysis catheters. PTA of the stenosis ⇨ was performed in a parallel to the catheter ➡ via basilic vein access. Right arm swelling resolved.*

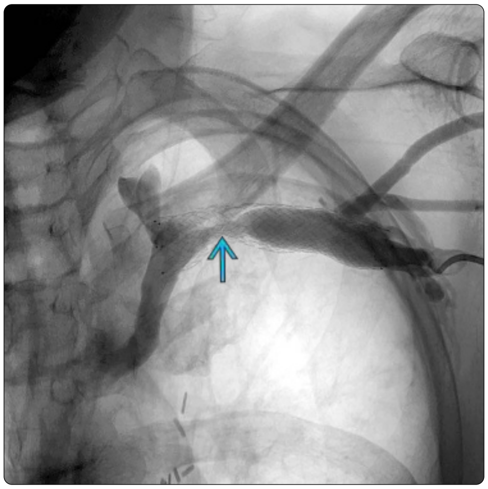
Secondary Axillosubclavian Vein Thrombosis (Diagnostic Venogram)



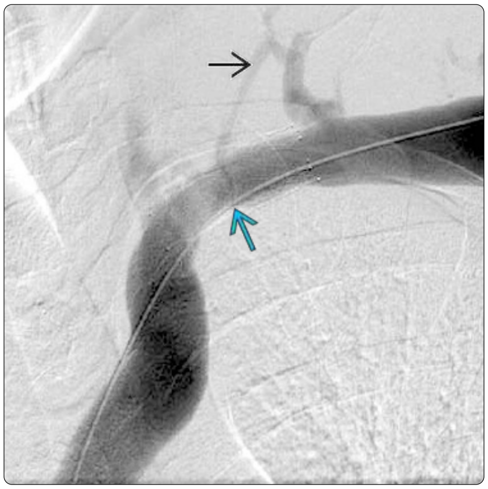
Secondary Axillosubclavian Vein Thrombosis (Angioplasty)



Recurrent Subclavian Vein Stenosis (In-Stent Restenosis)

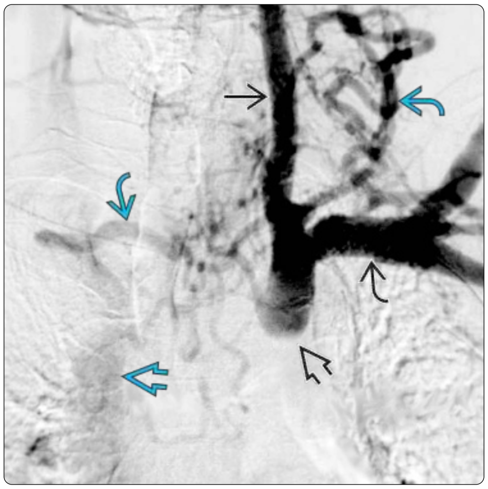


Recurrent Subclavian Vein Stenosis (Resolved Following Angioplasty)

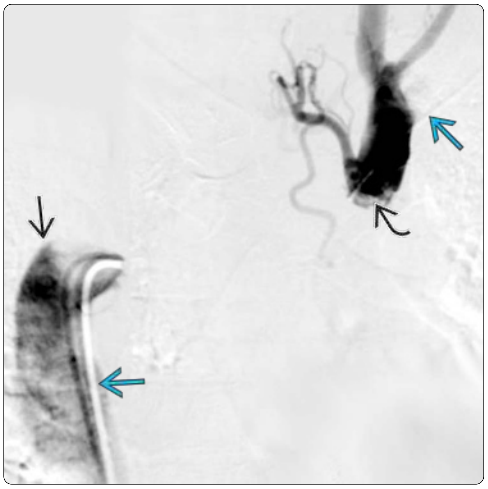


(Left) *A case of secondary ASVT as a result of hemodialysis access was treated with placement of a subclavian vein stent. In-stent restenosis commonly occurs with narrowing often located at the costoclavicular junction* →*.* **(Right)** *Following PTA, the stenosis is resolved and in-line flow restored through the subclavian vein* →*. Note decreased filling of associated collateral veins* →*.*

Brachiocephalic Vein Occlusion (Diagnostic Venography)

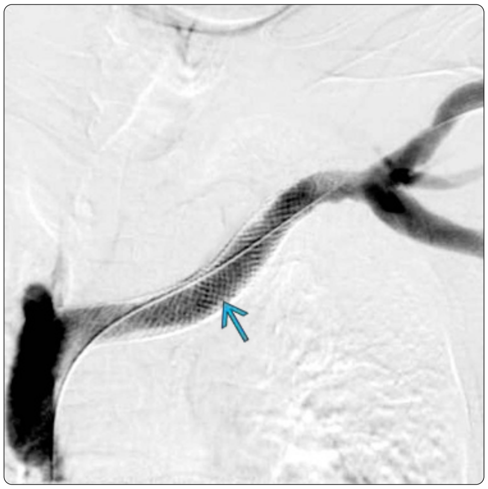


Brachiocephalic Vein Occlusion (Recanalization of Occlusion)

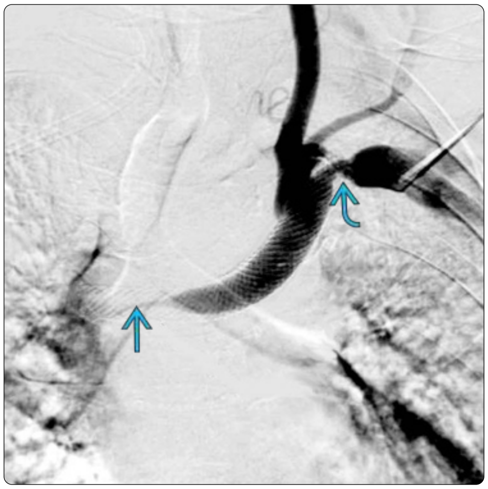


(Left) *DSA venogram in a hemodialysis patient with multiple prior central catheters shows an occluded left brachiocephalic vein* ⇨ *with dilatation of the internal jugular* → *and subclavian* ↪ *veins. There are extensive venous collaterals* ↪*, some of which drain into a faintly seen SVC* ⇨*.* **(Right)** *Catheters* → *were introduced into both the SVC* → *and the distal left brachiocephalic vein* ↪*. A guidewire was successfully passed from the SVC into the left subclavian vein, where it was snared.*

Brachiocephalic Vein Occlusion (Intravascular Stent Placement)

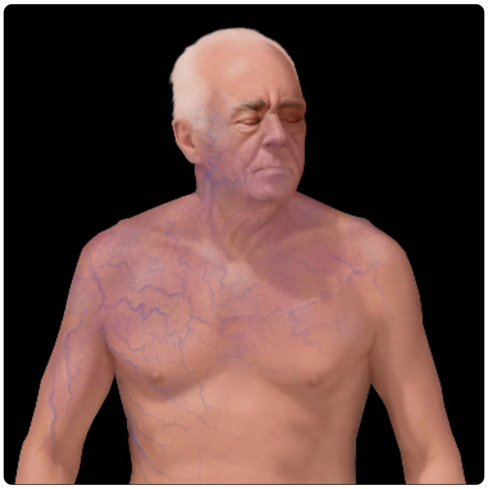


Brachiocephalic Vein Occlusion (In-Stent Restenosis)

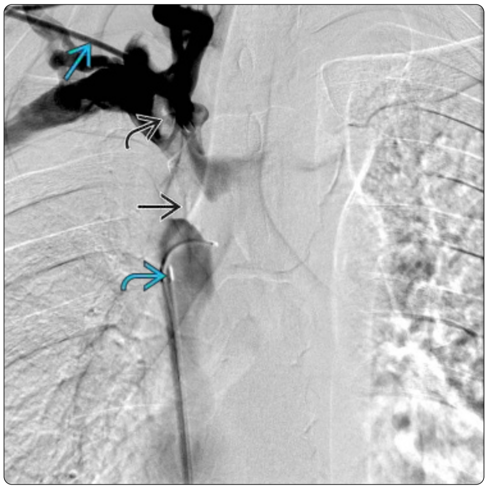


(Left) *PTA of the occluded brachiocephalic vein was performed; however, high-grade stenosis remained in the recanalized lumen. Therefore a large-diameter self-expanding Wallstent* → *was placed and postdilated with PTA.* **(Right)** *Three months later there was recurrent arm and facial swelling. Repeat DSA shows a severe in-stent stenosis* → *centrally and a moderate stenosis* ↪ *where the stent joins the subclavian vein. This delayed complication occurs frequently and is treated with angioplasty.*

(Left) *The graphic shows enlarged collateral veins in the face, neck, chest, and upper extremity suggesting underlying central venous occlusion.* **(Right)** *DSA venogram obtained during simultaneous contrast injection through external jugular → and SVC ↪ sheaths reveals total occlusion of the SVC at its superior aspect →. Note acute thrombus within the right brachiocephalic vein ↪.*

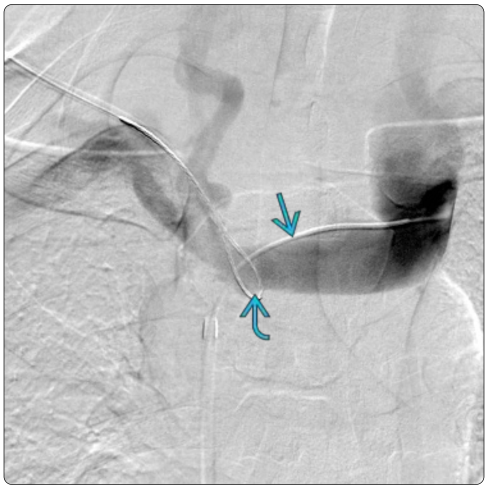


Collateral Vein Graphic

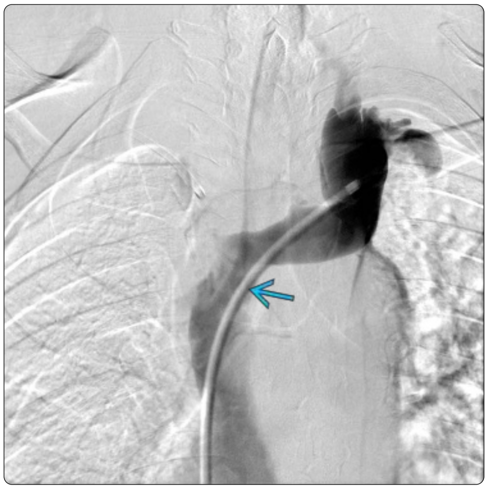


Occluded Right Brachiocephalic Vein (Diagnostic Venogram)

(Left) *The occlusion was inhibiting hemodialysis access and was therefore recanalized by advancing a radiofrequency wire and 4-Fr catheter → from the SVC across the occlusion, where it was snared ↪ from above.* **(Right)** *PTA was then performed of the occluded segment. No stent was necessary since there was no residual narrowing → on subsequent venography.*

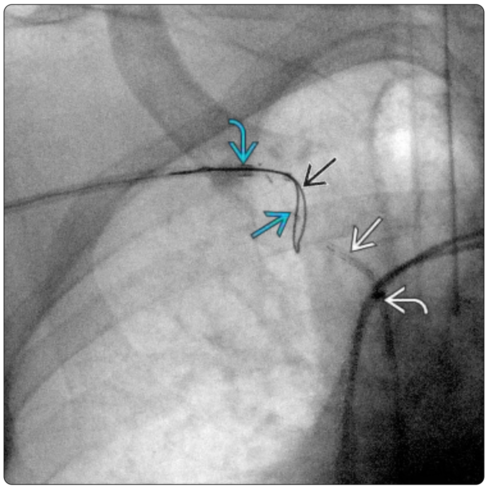


Occluded Right Brachiocephalic Vein (Recanalization)

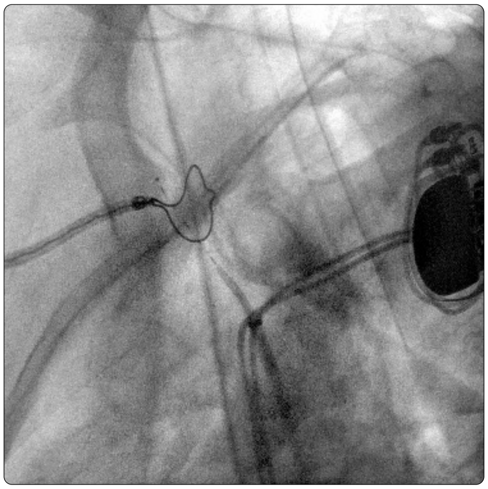


Occluded Right Brachiocephalic Vein (Post Angioplasty)

(Left) *A case of right brachiocephalic vein recanalization shows a radiofrequency wire → passed from an inferiorly-located catheter ➡ and sheath ➥, across the occlusion, and into a superiorly-located snare → advanced through an upper extremity sheath ↪.* **(Right)** *Visualization of endovascular instruments with steep obliquities is absolutely essential during central venous recanalization to ensure safety. Equipment seen in this obliquity is unchanged in position compared to the previous AP image.*

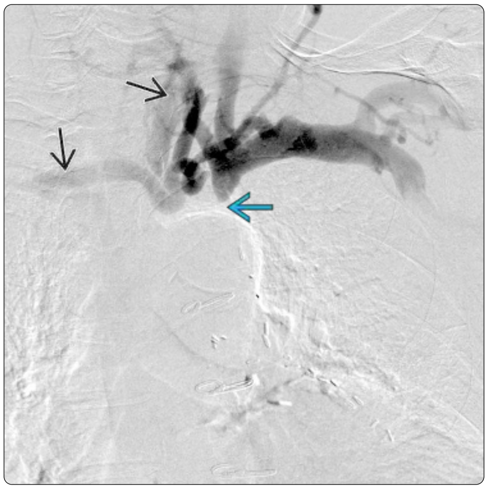


Occluded Right Brachiocephalic Vein (AP View During Recanalization)

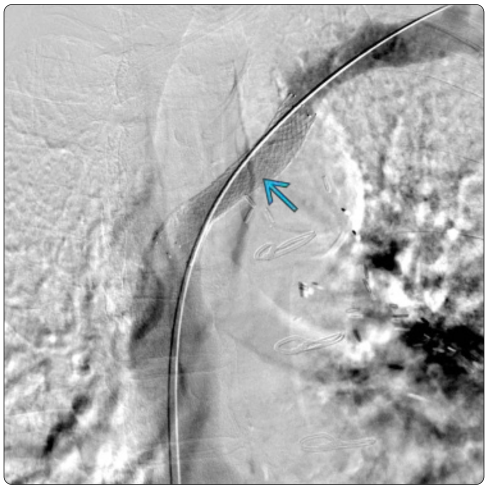


Occluded Right Brachiocephalic Vein (Oblique View During Recanalization)

Occluded Left Brachiocephalic Vein (Diagnostic Venogram)

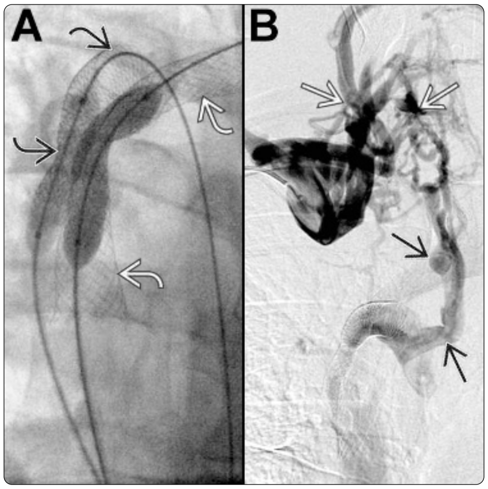


Occluded Left Brachiocephalic Vein (Post Stent Placement)

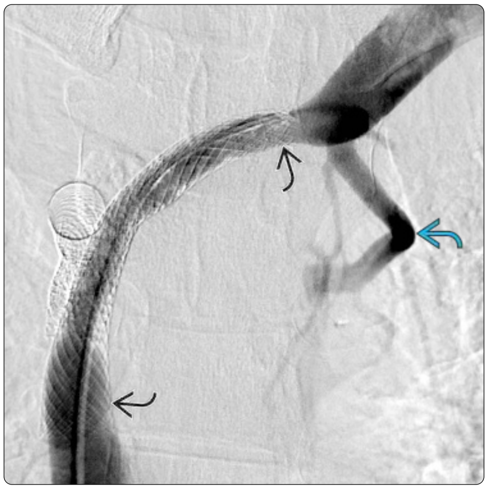


(Left) *A left arm hemodialysis fistulogram revealed occlusion of the left brachiocephalic vein ⇨ and enlarged draining venous collaterals in the right neck ⇨.* **(Right)** *Endovascular stenting of the recanalized brachiocephalic vein ⇨ was necessary to maintain patency. Venous drainage from the left arm is markedly improved, and the collaterals are no longer prominent.*

Upper SVC Obstruction (Parallel Stenting)

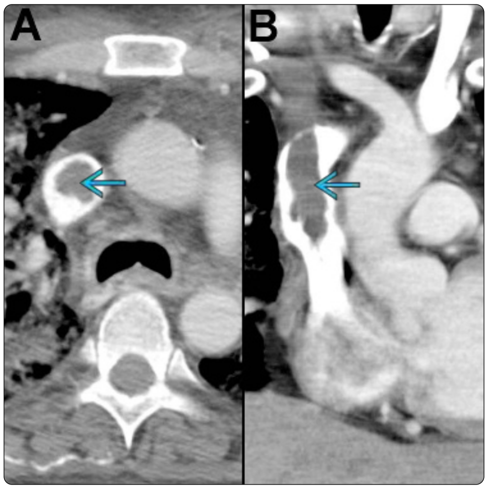


Upper SVC Obstruction (Parallel Stenting)

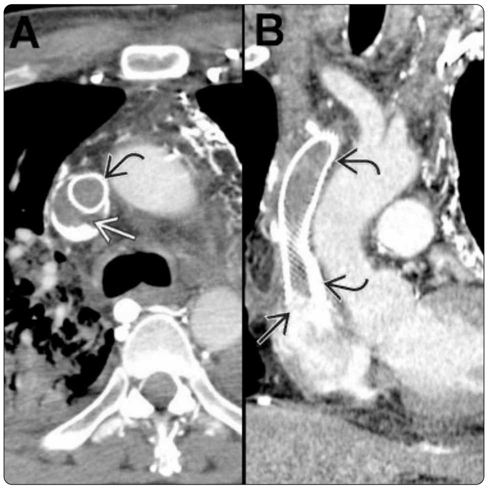


(Left) *Recanalization of the right brachiocephalic vein was not possible. Therefore, a stent ↪ was placed across the left brachiocephalic stenosis, while a parallel stent ↪ was placed into the azygos vein to maintain patency of that venous drainage route. Right subclavian DSA after parallel stenting shows the collaterals ➡ drain centrally ⇨.* **(Right)** *Left brachiocephalic DSA venogram shows good preferential central venous drainage through the other parallel stent ↪ rather than via the collaterals ↪.*

SVC Obstruction (Thrombosis as Etiology)



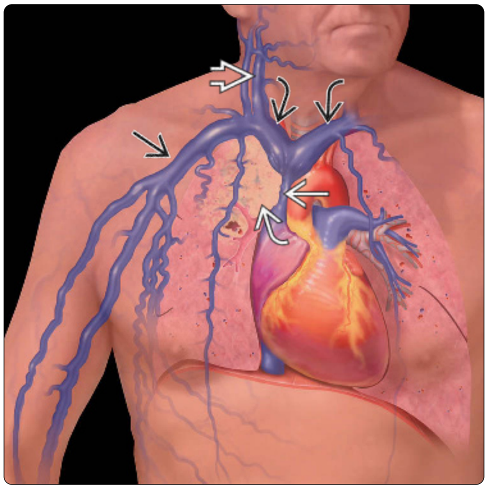
SVC Obstruction (Unsuccessful Stent Result)



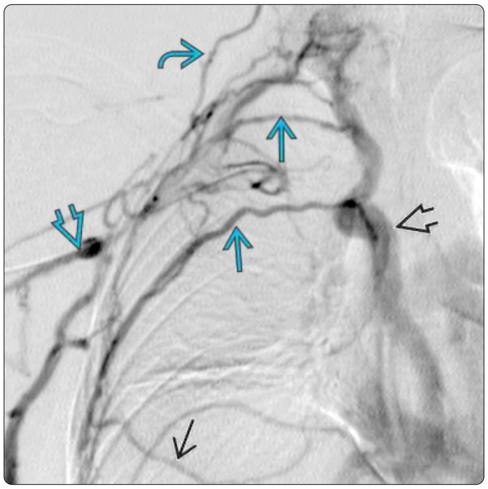
(Left) *(A) Axial and (B) coronal CECT reformation images show a large SVC thrombus ⇨. Clinically this caused head, neck, and bilateral upper extremity swelling, which did not improve despite 4 weeks of warfarin anticoagulation therapy.* **(Right)** *A noncovered Wallstent ↪ placed from the left brachiocephalic vein to the cavoatrial junction ⇨ failed to displace thrombus ➡. The swelling did not resolve.*

(Left) *Graphic shows a malignant stenosis ➡ of the upper SVC caused by invasion by lung cancer ➡, the most common etiology for malignant SVC obstruction. There is marked distension of the brachiocephalic ⇨, subclavian, and axillary ⇨ veins, as well as of the external and internal jugular ➡ veins.* **(Right)** *Right axillary DSA venography ⇨ shows extensive intercostal ⇨, neck ⇨, and chest wall ⇨ collaterals, providing venous return. The SVC is occluded, and thus central venous return is via the azygos vein ⇨.*

SVC Obstruction Graphic (Malignancy as Etiology)

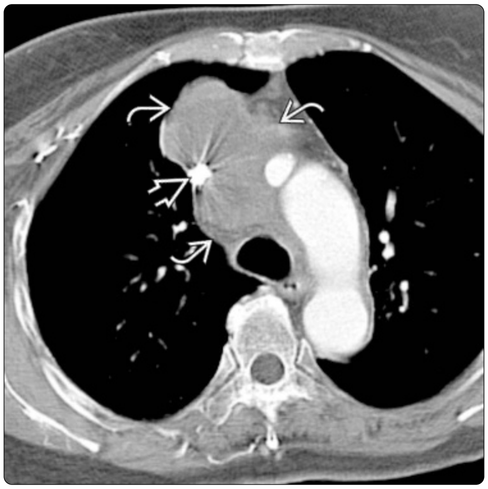


SVC Obstruction (Venographic Manifestations)

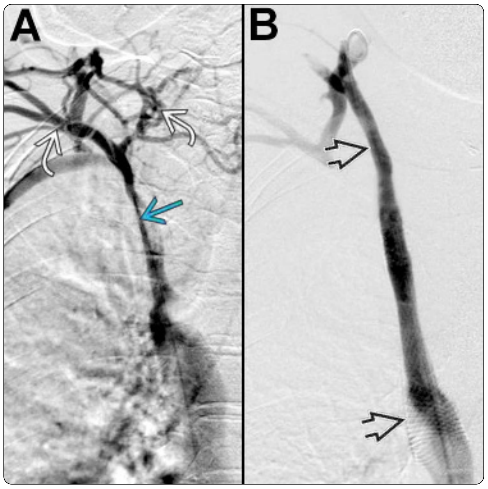


(Left) *Axial CECT obtained in a patient with known lung cancer presenting with head and neck swelling, shows a large mediastinal mass ➡ surrounding and significantly narrowing the SVC ➡.* **(Right)** *DSA shows (A) a severe irregular malignant stenosis ⇨, which correlates with the CECT findings. Dilated veins ➡ are seen above the obstruction. (B) The stenosis is markedly improved after placing a large-diameter self-expanding Wallstent ⇨. Symptoms rapidly improved.*

SVC Obstruction (Malignancy as Etiology)

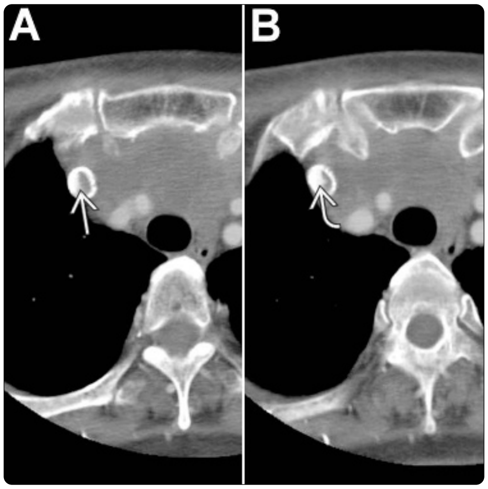


SVC Obstruction (Endovascular Stent Placement)

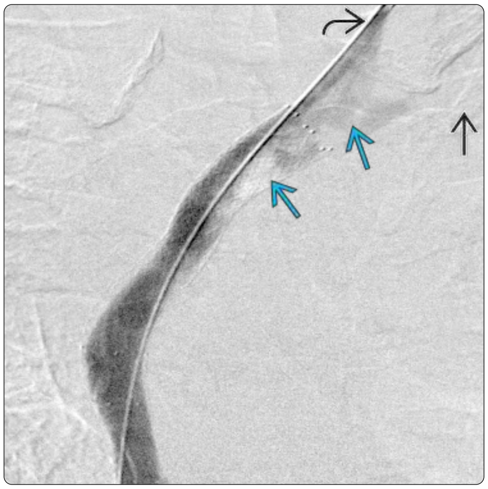


(Left) *CECT 3 months later shows (A) neoplastic tissue ingrowth ➡ into the stent, which almost completely occludes the lumen. This is a frequent problem in malignant obstruction. (B) Caudally there is a more patent lumen ➡.* **(Right)** *Venous wash-in ⇨ from nonopacified veins can have a similar appearance to tissue ingrowth and thrombus formation. Wash-in from the subclavian vein ⇨ in this DSA completely resolved with increased internal jugular ⇨ contrast volume injected during Valsalva maneuvers.*

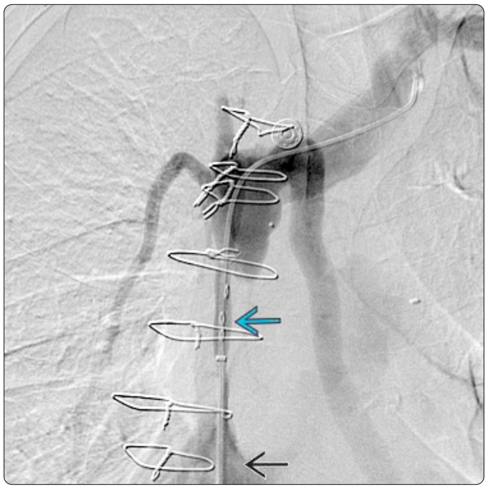
SVC Obstruction (Neoplastic Stent Invasion)



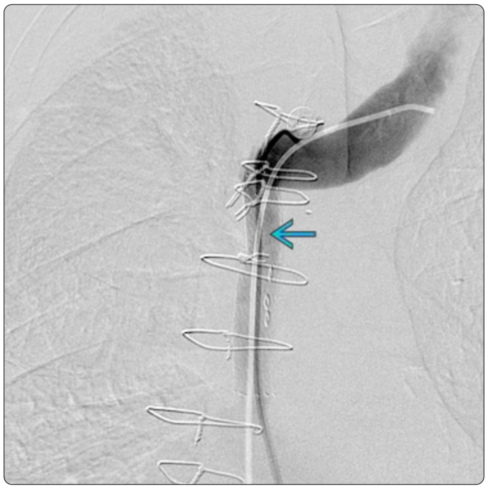
Venous Wash-In (Artifact)



Malignant SVC Stenosis (Diagnostic Venogram)

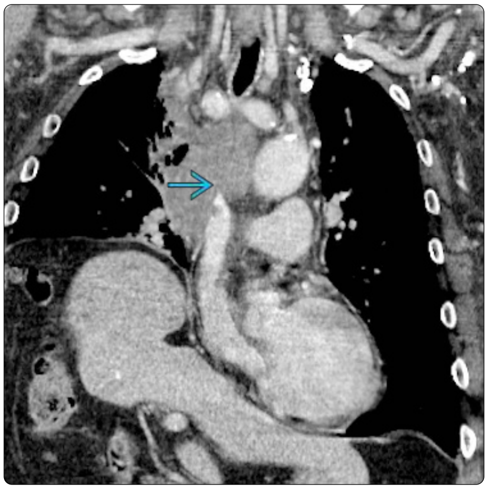


Malignant SVC Stenosis (Post Stent Placement)

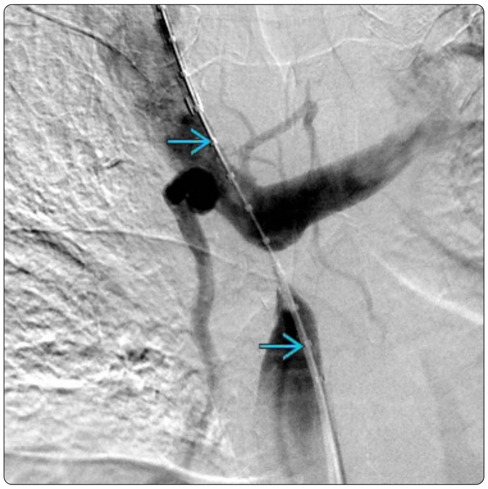


(Left) *DSA venography performed in a patient with known malignant encasement of the SVC → shows that the stenosis extends inferiorly to the right atrium →. Endovascular treatment of this location must be performed with extreme caution. The pericardium often extends superiorly along the SVC, and SVC injury can result in life-threatening pericardial tamponade.* **(Right)** *A conservative 14-mm diameter self-expanding stent → was used to restore flow to the SVC, resulting in rapid resolution of symptoms.*

Malignant SVC Obstruction

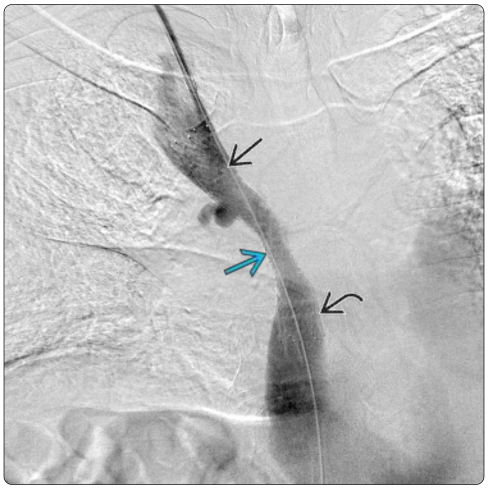


Malignant SVC Obstruction (Obtaining Measurements)

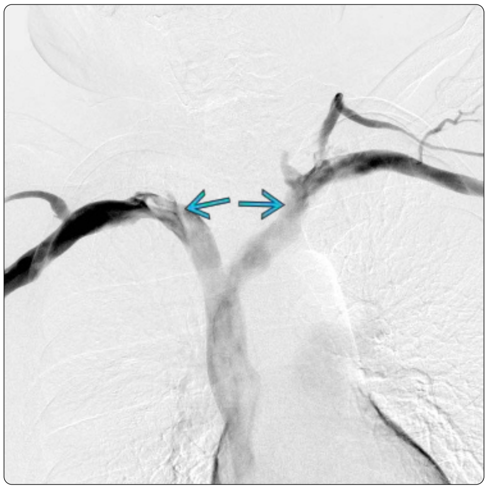


(Left) *Coronal CECT imaging shows a malignant mediastinal mass occluding the superior portion of the SVC →.* **(Right)** *The SVC occlusion was crossed and DSA venography performed with a marker catheter in place →. The 1-cm marks were used to plan the necessary stent diameter and length. Contrast was simultaneously injected through the right internal jugular sheath and through the catheter in order to fill vessels above and below the obstruction.*

Malignant SVC Obstruction (Post Stent Placement)



Normal Bilateral Central Venogram



(Left) *A self-expanding stent was deployed from the right brachiocephalic vein → into the SVC ↷, restoring flow across the SVC obstruction →. Factors to consider include the probability of tumor ingrowth, risks of jailing covered vessels, and overall life-expectancy when deciding whether to place a covered or noncovered stent.* **(Right)** *A normal central venogram obtained with bilateral upper extremity intravenous contrast injection. Note normal wash-in from unopacified internal jugular veins →.*

Lower Extremity Veins and IVC Intervention

KEY FACTS

TERMINOLOGY

- **Postthrombotic syndrome (PTS)**: Late DVT sequela
    - Result of chronic venous hypertension from valvular reflux & venous obstruction
    - Occurs in 20-40% of iliofemoral DVT within 2 years
- **Catheter-directed thrombolysis (CDT) & pharmacomechanical thrombolysis (PMT)**
    - Endovascular means of potentially enhancing thrombolysis over systemic thrombolysis

PROCEDURE

- **Expert recommendations regarding treatment of DVT**
    - Optimal treatment recommendations remain controversial & not well established
    - Early thrombus removal with CDT/PMT should be considered for younger patients with good functional status, acute onset of symptoms (< 14 days), & iliofemoral or caval involvement, or those with limb-threatening venous ischemia
    - Anticoagulation without CDT/PMT recommended for isolated femoropopliteal DVT
    - Majority of patients with DVT should likely be treated with systemic anticoagulation alone
- **Periprocedural IVC filter placement**
    - Generally recommend against IVC filter for patients with acute DVT or PE treated with anticoagulation
        - May not apply when DVT extends into IVC, or markedly limited cardiopulmonary reserve
- **Chronic iliocaval obstructive/compressive lesions**
    - Recommend use of self-expanding metallic stents to restore patency/resolve stenosis

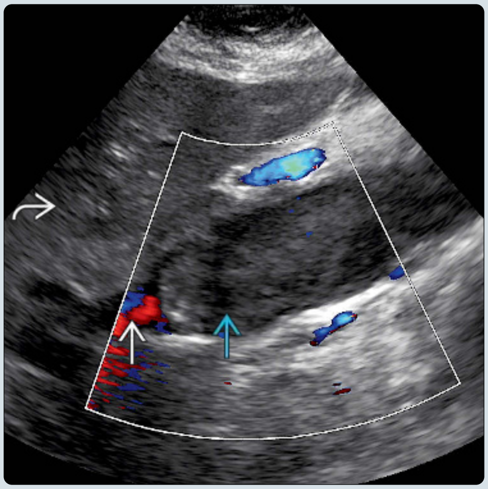
POST PROCEDURE

- Systemic anticoagulation (typically 3 months or extended)
- Elastic compression stockings no longer recommended

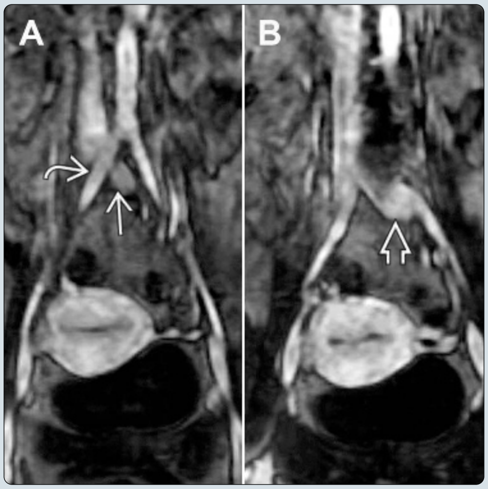
OUTCOMES

- CDT/PMT of DVT may decrease risk of moderate-to-severe PTS vs. conventional therapies in appropriate cases

IVC Thrombosis

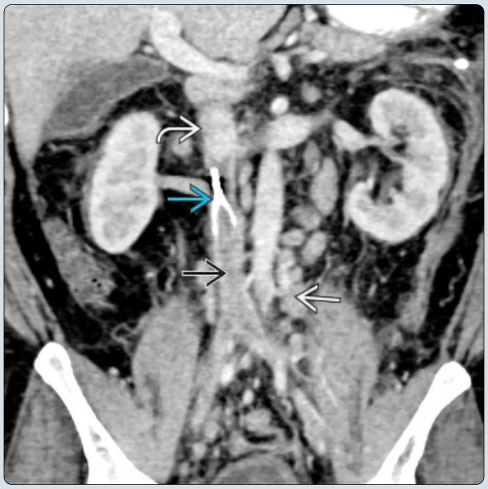


May-Thurner Syndrome

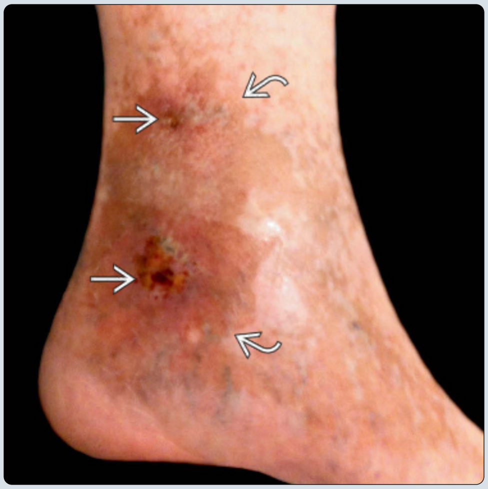


(Left) *Sagittal ultrasound of the abdomen shows thrombus* ⇨ *extending superiorly within the inferior vena cava (IVC) to the liver, where a metastasis is partially visualized* ↷*. Patent flow remains within the intrahepatic portion of the IVC* ➡*.* **(Right)** *Coronal MRA shows (A) the right common iliac artery* ↷ *as it crosses anterior to the left common iliac vein* ➡ *near the iliac confluence that forms the IVC. (B) The left common iliac vein is dilated* ⇨ *proximal to the area of compression.*

IVC Thrombosis Management (Diagnostic CECT Imaging)



Late Sequela of Chronic DVT



(Left) *Coronal CECT reconstruction shows an IVC filter* ⇨ *with enhancement of the suprarenal IVC* ↷ *above the filter but low-attenuation, nonenhancing thrombosis of the infrarenal IVC* ⇨*. Also seen are enhancing serpiginous venous collaterals* ➡*.* **(Right)** *Clinical photograph shows typical changes of venous insufficiency/postthrombotic syndrome. Two venous stasis ulcers* ➡*, extensive hyperpigmentation* ↷*, and soft tissue swelling are seen.*

TERMINOLOGY

Synonyms

- May-Thurner syndrome = Cockett syndrome, iliac vein or iliocaval compression syndrome
- Femoral vein = superficial femoral vein

Definitions

- **Venous thromboembolism (VTE)**
  - Includes deep vein thrombosis (DVT) & pulmonary embolism (PE)
  - Significant source of morbidity & mortality
  - Occurs in 1:1000 people yearly
- **Catheter-directed thrombolysis (CDT)**
  - Delivery of fibrinolytic agent directly into thrombus via intravascular catheter
  - Allows increased dose of fibrinolytic into thrombus
  - Decreases fibrinolytic bypassing thrombus via collaterals
  - May decrease total fibrinolytic dose, treatment/hospitalization time
- **Pharmacomechanical thrombolysis (PMT)**
  - Thrombolytic infusion + mechanical thrombus disruption
  - Increases contact area between fibrinolytic & thrombus
  - May improve thrombolytic action, further decreasing fibrinolytic dose & treatment/hospitalization time
- **Chronic venous insufficiency (CVI)**
  - Venous reflux & ambulatory venous hypertension
  - Result of damaged, incompetent valves & venous obstruction
- **DVT**: Formation of blood clot(s) in deep veins (usually lower extremities), often accompanied by inflammation (thrombophlebitis)
  - Anatomic distribution
    - **Iliofemoral DVT**: Includes any part of iliac vein &/or common femoral vein (CFV)
    - **Femoropopliteal DVT**: Involvement limited to popliteal, femoral, &/or deep femoral veins
    - **Calf DVT**: Involves any of paired deep calf veins
      - Peroneal, anterior, &/or posterior tibial veins
      - Calf DVT does not include popliteal vein
  - Duration of positive DVT symptoms/imaging tests
    - Acute DVT: < 14 days duration
    - Subacute DVT: 15-28 days duration
    - Chronic DVT: > 28 days duration
  - DVT involves left leg 3-5x more than right
    - Likely due to May-Thurner anatomy/syndrome
  - More severe initial symptoms with iliofemoral compression/occlusion than with more distal DVT
    - Much greater likelihood of developing postthrombotic syndrome (PTS)
  - Responsible for > 250,000 hospitalizations in USA/year
  - Risk factors: Acute medical illness, antiphospholipid syndrome, active cancer, inherited thrombophilia, later age, long-distance travel, major trauma, obesity, oral contraceptives/hormone replacement therapy, paralytic stroke or immobilization, pregnancy, previous VTE, recent surgery, varicose veins
- **PTS**: Late DVT sequela
  - 20-40% of 1st-time, acute, iliofemoral DVT develop PTS within 2 years
    - 5-10% develop severe PTS
    - Recurrent ipsilateral DVT associated with 2-6x ↑ risk PTS
  - Result of chronic venous hypertension
    - Due to valvular reflux & venous obstruction
      - Post-DVT valvular damage leads to reflux
      - Thrombosed veins impair venous return
  - Villalta scale of PTS: Evaluate severity of PTS
    - Scoring with rating for each sign/symptom of 0 (none), 1 (mild), 2 (moderate), 3 (severe)
      - < 5 = no PTS, 5-14 = mild/moderate PTS, ≥ 15 = severe PTS
    - Patient symptoms
      - Pain (at rest or with ambulation), cramping, heaviness, itching, numbness
    - Clinical signs
      - Redness, hyperpigmentation, skin induration, venous ectasia, pretibial edema
    - Additional signs/symptoms
      - Venous claudication, skin lipodermatosclerosis & ulceration, worsening of symptoms with upright position/activity
- **May-Thurner anatomy**: Incidental finding; no associated DVT
  - Left iliac vein compressed obliquely & anteriorly by right iliac artery
    - Right iliac artery compresses vein against spine
    - Occurs near iliac venous confluence into inferior vena cava (IVC)
  - Very common finding
    - Incidence: Female (41%) > male (27%)
    - Rarely symptomatic
- **May-Thurner syndrome**: Symptomatic finding; DVT present
  - Left iliac vein compressed obliquely & anteriorly by right iliac artery
    - Right iliac artery compresses vein against spine
    - Occurs near iliac venous confluence into IVC
    - Produces endoluminal fibrous venous scar
      - Well seen by intravascular ultrasound (IVUS)
      - Termed venous "spur" by surgeons & pathologists
- **Phlegmasia alba dolens**: Massive venous thrombosis-associated lower extremity swelling **without** cyanosis
- **Phlegmasia cerulea dolens**: Massive venous thrombosis-associated lower extremity swelling **with** limb-threatening cyanosis of lower extremity
- **Proximal/distal thrombus**: Society for Vascular Surgery (SVS) recommends use of precise anatomic terminology (e.g., iliofemoral, femoropopliteal, calf) over characterization of thrombus as proximal/distal
  - Include ± extension into IVC

PREPROCEDURE

Indications

- Consider endovascular therapy currently with these therapeutic goals
  - Treat severe manifestations of VTE
    - Acute limb-threatened venous occlusion (i.e., phlegmasia cerulea dolens)
    - Threatened life, organ
  - Reduce short-term affects of VTE

    - Progression of VTE despite current anticoagulant therapy
    - Hasten relief of DVT-associated symptoms
  - Potentially reduce long-term risk associated with VTE
    - Reduce risk of PTS (CaVenT trial)
    - Possibly reduce valvular damage & subsequent reflux & venous obstruction
- Consider treatment for
  - Functional patient with low bleeding risk & normal life expectancy
    - Acute femoropopliteal DVT, if severely symptomatic or anticoagulant refractory
    - Acute iliofemoral DVT
    - Symptomatic subacute/chronic iliofemoral DVT
    - Acute/subacute/chronic IVC thrombosis
  - Less functional, moderate bleeding risk patients, irrespective of life expectancy
    - Symptomatic acute/subacute IVC thrombosis
    - Phlegmasia cerulea dolens; for limb salvage
  - Consider withholding treatment for
    - Asymptomatic DVT
    - Isolated popliteal or calf DVT
- Additional considerations regarding early thrombus removal
  - Location of DVT (e.g., iliofemoral, extension to IVC)
  - Acuity of thrombus (e.g., symptomatic < 14 days)
  - Patient's life expectancy (e.g., ≥ 1 year)
  - Baseline ambulation/activity
  - Risk of bleeding
  - Patient wishes following discussion of risks/benefit/alternatives
- Treatment of DVT with endovascular therapy remains controversial
  - CDT may ↓ PTS without improving quality of life
  - CDT may be associated with ↑ transfusion, CDT-associated bleed, PE, IVC filter placement
  - ATTRACT (**a**cute venous **t**hrombosis: **T**hrombus **r**emoval with **a**djunctive **c**atheter-directed **t**hrombolysis) trial nearing completion, may resolve some controversy regarding CDT/PMT & PTS
- Systemic anticoagulation remains accepted mainstay therapy for VTE
  - Prevents PE, thrombus extension, VTE recurrence
  - 20-40% patients properly treated with anticoagulant therapy develop PTS

Contraindications

- **Absolute contraindications**
  - Active bleeding/uncorrectable coagulopathy
  - History of hemorrhagic/recent ischemic stroke
  - Recent head trauma/intracranial surgery (< 3 months)
  - Intracranial neoplasm
- **Major relative contraindications**
  - Remote ischemic stroke (> 3 months)
  - Recent major thoracic/abdominal surgery (≤ 3 weeks)
  - Recent major trauma (≤ 4 weeks)
  - Recent gastrointestinal hemorrhage (≤ 3 months)
  - Prolonged or traumatic CPR (> 10 minutes)
  - Uncontrolled hypertension
- **Minor relative contraindications**
  - Pregnancy
  - Infected thrombus
  - Renal or hepatic insufficiency (bleeding risk)

Getting Started

- Things to check
  - History
    - History of acute episode
      - Pain, edema, cyanosis, claudication
      - Skin changes (e.g., hyperpigmentation, skin ulcer)
      - Duration, start date
      - Location (unilateral, bilateral), (calf, thigh, buttock)
    - VTE risk factors
      - Prior VTE
      - Hypercoagulable (e.g., factor V Leiden)
    - Current medications
      - Anticoagulants, antiplatelet agents
      - Missed doses, doses withheld
    - Any symptoms of PE
      - Tachypnea, dyspnea, chest pain, palpitations
    - Presence of IVC filter
  - Physical exam
    - Vital signs: Heart rate, blood pressure, respiratory rate, oxygenation
    - Extremity: Edema, skin ulceration/hyperpigmentation, superficial varicosities
  - Allergies (e.g., heparin, contrast, sedative medications)
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - Complete blood count
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ratio ≤ 1.5
      - Fibrinogen level
      - Hypercoagulability evaluation (following acute episode)
    - D-dimer (review if present)
      - Degradation product of cross-linked fibrin
      - High sensitivity (in acute thrombosis)
      - Low-moderate specificity (elevated in malignancy, infection, pregnancy, increasing age)
      - High negative predictive value (few false-negative results)
      - Negative result helps exclude acute VTE
  - Postprocedure planning
    - In-patient bed available for potential CDT [tissue plasminogen activator (tPA) monitoring]
      - Hospital protocols often require ICU or step-down unit during tPA delivery
    - Anticoagulation/antiplatelet management
      - Consult appropriate service to initiate/follow as outpatient
      - 2016 CHEST guidelines regarding agent, duration, & subsequent work-up
  - Consent
    - Venography: Risk of contrast-induced nephropathy, vessel injury from wires/catheters
    - Thrombolysis: Risk of death, intracranial bleed (stroke), bleed from additional site, access hematoma

        - Venous occlusion/stenosis: Potential injury during vessel recanalization, pain during angioplasty, suboptimal stent positioning
        - Treatment planning
            - Discuss existing limitations in regards to best clinical practice guidelines
            - Discuss unexpected intraprocedural findings (e.g., chronic occlusion/thrombus, duplicated veins, indeterminate flow-limitations of venous stenosis)
- Medications
    - IV heparin, 2,000-5,000 units intraprocedural
    - Thrombolytic agent(s)
        - Various agents available
            - tPA; alteplase
            - Recombinant tPA (rPA; reteplase; tenecteplase)
            - Urokinase
        - Incremental doses administered locally through catheter placed within thrombus
    - Low molecular weight heparin (LMWH)
        - Use as bridge from preprocedural & to postprocedural warfarin therapy
    - Sedative/analgesic agents: Typically versed & fentanyl
        - Initial access not overly painful following lidocaine administration
        - Crossing venous obstructions, angioplasty, stent placement may be extremely painful
        - Procedure may be lengthy if thrombus nonacute, venous obstruction present
- Equipment list
    - Micropuncture set for venous access
    - Guidewires
        - 0.035" starter guidewire
        - Angled or straight-tipped hydrophilic (e.g., Glidewire, Roadrunner)
            - Used for crossing thrombosed segment(s)
        - Stiff guidewire (e.g., Amplatz, Rosen, Lunderquist)
            - Gives stability for angioplasty or stenting
    - Catheters & sheaths
        - Vascular access sheath
            - Typically start with 5 Fr x 11 cm sheath
            - May upsize to 8-10 Fr x 50 cm for suction aspiration
        - Selective catheter(s)
            - Directional diagnostic 5 Fr for pushability (e.g., Kumpe/Berenstein)
            - Hydrophilic 4-5 Fr to traverse chronic occlusions
        - Flush catheter(s)
            - Pigtail/Omni Flush (with 1-cm markers to aid measurements prior to stent placement)
    - Percutaneous transluminal angioplasty (PTA) balloon catheter
        - Diameter/length based on target lesion(s)
        - High-pressure balloon usually required
    - Thrombolysis equipment
        - Possis AngioJet (Medrad)
        - ThromCat system (Kensey Nash)
        - Trellis system (Bacchus Vascular)
        - EkoSonic catheter system (Ekos)
        - Indigo mechanical thrombectomy system (Penumbra)
    - Self-expanding, noncovered stents
        - Wallstent (Boston Scientific)
        - Protégé GPS (Covidien)
        - S.M.A.R.T. Control (Cordis)

Society Guidelines

- College of Chest Physicians Clinical Practice Guidelines (2016)
    - Endovascular DVT treatment recommendations
        - Acute proximal DVT of leg: Systemic anticoagulant therapy alone suggested over CDT
        - Risk & benefit of CDT remain uncertain; therefore anticoagulant therapy alone is acceptable alternative to CDT in all patients with acute DVT, if no impending venous gangrene
        - CDT most likely to benefit patients with
            - Iliofemoral DVT
            - Symptoms < 14 days
            - Good functional status
            - Life expectancy ≥ 1 year
        - Overall quality of evidence is improving, but still low (grade 2C)
    - Periprocedural IVC filter placement
        - Recommend against IVC filter for patients with acute DVT or PE treated with anticoagulation (grade 1B)
            - May not apply in subgroup of patients with severe PE (e.g., hypotensive)
    - Suggest **no** compression stockings (to prevent PTS)
        - Change from 2012, CHEST 9th edition recommendations, which recommended compression stockings
        - Changes made citing 2014 SOX trial
- SVS & American Venous Forum Clinical Practice Guidelines (2012)
    - Endovascular DVT treatment recommendations
        - Suggest early thrombus removal for the following criteria (grade 2C)
            - Iliofemoral DVT, 1st episode
            - Symptoms < 14 days
            - Acceptable life expectancy, ambulatory, good functional capacity
            - Low risk of bleeding
        - Recommend early thrombus removal for limb-threatening venous ischemia due to iliofemoral DVT (grade 1A)
        - Recommend conventional anticoagulation for isolated femoropopliteal DVT (grade 1C)
    - Suggested techniques for early thrombus removal
        - Catheter-based techniques (CDT or PMT)
        - Consider PMT over CDT if expertise & resources available
        - Surgical venous thrombectomy if thrombolytic therapy contraindicated
    - Periprocedural IVC filter placement
        - Recommend against use of IVC filter in conjunction with CDT
        - Consider risk/benefit of IVC filter when DVT extends into IVC or markedly limited cardiopulmonary reserve
    - Adjunctive use of venous stents
        - Recommend use of self-expanding metallic stents to treat chronic iliocaval obstructive/compressive lesions
        - Suggest stents not used in femoral & popliteal veins

  - ○ Early thrombus removal as adjunct to conventional management
    - – Recommend treatment with standard course of systemic anticoagulation after procedure

PROCEDURE

Procedure-Specific Goals

- Diagnostic venography
  - ○ Determine anatomic extent of DVT, including IVC involvement
  - ○ Determine acuity/chronicity of DVT based on angiographic appearance & clinical history
- Thrombolysis of acute/subacute DVT
  - ○ Initiate systemic anticoagulation, CDT, or PMT
- Treatment of underlying venous occlusion/stenosis
  - ○ Consider treating iliac lesion with stent; angioplasty only for femoropopliteal lesion

Patient Position/Location

- Ideally, plan to pass wires/catheters with normal flow of valves, not against
- Appropriate point for venous access depends on anatomic level(s) involved
  - ○ Femoropopliteal DVT/occlusion
    - – Popliteal or small saphenous vein access
  - ○ Iliofemoral & femoropopliteal DVT/occlusion
    - – Popliteal vein access typical
  - ○ Iliocaval DVT/occlusion
    - – Femoral vein access (bilateral to treat iliac confluence)
    - – May access via great saphenous vein
    - – May also require internal jugular vein access

Procedure Steps

- **Obtain percutaneous access**
  - ○ Venous access with US guidance
    - – Do not expect blood return through needle in thrombosed vein
    - – May use micropuncture set to obtain access
      - ☐ 0.018" steel guidewire may not pass through chronic organized thrombus
      - ☐ Consider speciality wire (e.g., .014 silicone-coated Nitrex, Covidien)
      - ☐ Consider using 19-g needle/0.035" guidewire if microwire will not advance
    - – Place transitional dilator/stiff dilator
      - ☐ Exchange 0.018" for 0.035" guidewire
- Consider placing long 6- to 7-Fr guiding sheath, which will reach DVT/occlusion
  - ○ Provides increased catheter/guidewire support when crossing occlusion
- **Diagnostic venogram (inferior approach)**
  - ○ Perform DSA venogram via access sheath or catheter
    - – Define anatomy & inferior extent of stenosis/occlusion
      - ☐ Obtain DSA images; multiple views as needed
      - ☐ Breath-hold may aid IVC imaging
      - ☐ Collaterals may bypass occlusion, obscure true course of vessel
      - ☐ Real-time visualization of blood-flow bypassing lesion through collaterals suggests hemodynamic significance of lesion
  - ○ Advance guidewire superior to stenosis/thrombosis
    - – Hydrophilic guidewire optimal for crossing lesion
    - – Sequentially advance guidewire short distance followed by catheter; repeat sequence
    - – Embed catheter tip into edge of thrombus, then advance hydrophilic guidewire
    - – Use contrast injections while crossing thrombosis to confirm intraluminal position
    - – Advance guidewire beyond occlusion into IVC for stability
    - – Advance hydrophilic catheter over guidewire superior to occlusion
    - – Define superior extent of DVT
      - ☐ Confirm catheter tip position with contrast hand injection
      - ☐ Perform inferior cavogram with breath-hold DSA (note anatomy, thrombus, IVC filter)
      - ☐ Replace hydrophilic guidewire with stiff guidewire (e.g., Amplatz, Rosen) into IVC
- **CDT**
  - ○ May be used as stand-alone therapy or following mechanical thrombolysis
    - – Initial debulking of thrombus; then use CDT to lyse any residual thrombus
  - ○ Measure length of DVT
    - – Place catheter to superior extent of thrombus; place mark on catheter at sheath
    - – Pull catheter back to inferior aspect of thrombus; place mark on catheter at sheath
    - – Measure distance between catheter marks
  - ○ Choose appropriate multiple sidehole infusion catheter
    - – Must traverse entire length of thrombus; catheter slightly longer than thrombus is acceptable
    - – Catheter must not be shorter than length of thrombus
  - ○ Initiate CDT
    - – Typically plan CDT for > 6 hours/overnight/multiple days
    - – Typical infusion: tPA 0.5-1.0 mg/h
      - ☐ Divide dose if bilateral infusion catheters
    - – Monitor fibrinogen levels at least every 6 h
      - ☐ Low levels increase bleeding complication rate
      - ☐ If fibrinogen level < 150 mg/dL, cut in 1/2 rate (dose) of thrombolytic agent
      - ☐ If fibrinogen level ↓ > 1/2 in any 6-h period, cut in 1/2 rate of thrombolytic agent
      - ☐ If fibrinogen level < 100 mg/dL, stop thrombolytic agent, replace with normal saline through catheter at same rate
    - – Monitor patient in ICU/step-down unit
    - – Repeat venography at intervals to assess progress
  - ○ May need additional interventions after CDT
    - – Thrombectomy/angioplasty/stenting
  - ○ **US-accelerated CDT**: EKOS EndoWave (EKOS Corp)
    - – Utilizes US/acoustic-assisted CDT
    - – Low-power US energy emitted into thrombus along with fibrinolytic agent
    - – May reduce treatment time, lytic agent dose vs. standard CDT
    - – Initiate same as CDT (catheter length, tPA rate, fibrinogen/ICU monitoring)

- EkoSonic endovascular system received FDA-approval for treatment of PE
- **PMT**
  - Combines mechanical clot disruption with thrombolytic infusion
    - Mechanical thrombectomy (without tPA), 26% thrombus removal
  - PMT with tPA highly effective for clot burden removal
    - Effective with chronic occlusion/thrombosis
    - May require multiple passes with device
    - Treatment times of 60-90 min possible
    - May require subsequent CDT after PMT
      - Overall shorter treatment times compared with CDT alone
      - Potential cost savings due to shorter ICU stay
  - PMT does not adversely affect function of involved valves
  - Caution: Ensure adequate anticoagulation (IV heparin) during PMT
  - **Rheolytic PMT**: AngioJet, Medrad, Inc
    - Disrupts & aspirates clot via Venturi vacuum effect
    - ↓ ICU/hospital stay; ↑ hemoglobinuria/renal dysfunction
- **Angioplasty**
  - Can use angioplasty balloon to macerate clot
    - Mechanical disruption prior to thrombolysis
  - May perform focal angioplasty of venous stenoses
    - Consider ancillary stenting if poor result
    - Be aware of increased thrombogenicity of venous endothelium after thrombolysis
- **Stenting**
  - Primarily used in iliocaval venous procedures
    - Need large diameter (e.g., 12- to 16-mm) stents in iliocaval segment
      - Stents often extend from pelvis into IVC
      - Self-expanding, noncovered stents often used
      - Some stents significantly shorten in length as diameter increases (e.g., Wallstent)
    - Place smaller diameter iliac stent(s) 1st
      - Extend centrally with larger stents, overlapping from within smaller stent
    - Poststent angioplasty required to anchor stent in position
  - Can be used in iliofemoral segment if needed
  - Stents continue to improve (flexibility/less metal fatigue) due to advances in stent materials/design/construction
  - May-Thurner syndrome best treated with large diameter self-expanding stent after thrombolysis
- **Anatomic considerations**
  - **Femoropopliteal segment**: Femoral &/or popliteal vein thrombosis
    - Popliteal access with patient prone
    - Perform DSA venography of popliteal/femoral/CFVs
      - Determine extent of thrombosis
    - Proceed with PMT or CDT thrombolysis
      - May perform focal PTA (e.g., 6- to 8-mm diameter) of venous stenoses
    - If venous stenoses persist after thrombolysis & PTA, stenting may be needed
    - Must treat iliofemoral/iliocaval occlusion, or femoropopliteal segments will reocclude
  - **Iliofemoral segment**: Femoral/iliac vein thrombosis
    - Perform DSA after gaining popliteal access
      - Determine extent of thrombosis
    - Proceed with PMT or CDT thrombolysis
    - Inflow into pelvis & iliocaval outflow needed to maintain patency
      - May need to treat inflow with PTA & stenting
      - Prone position can compress CFV against fluoro table (not stenosis)
  - **Iliocaval segment**: Thrombosis of iliac veins/IVC
    - Exclude May-Thurner syndrome as etiology
      - Left iliac vein compressed by right iliac artery
      - Iliolumbar collaterals present
      - IVUS may be useful for evaluation; can identify May-Thurner venous "spur"
    - If May-Thurner syndrome identified
      - Stenting usually needed to maintain iliac vein patency after thrombolysis
      - May need kissing stents extending from both common iliac veins into IVC
      - Unilateral stent should usually extend into IVC
    - If IVC thrombosis related to indwelling IVC filter
      - Recanalize through occlusion into patent segment
      - Consider filter removal after thrombolysis
      - If permanent filter, may need to place bilateral stents from iliac veins; extend into IVC beyond tip of filter
    - Thrombosis may be due to IVC atresia (rare)
      - May not need thrombolysis if sufficient collateral drainage

Alternative Procedures/Therapies

- Surgical
  - Surgical thrombectomy
  - Valvuloplasty/venous valve reconstruction surgery
    - Suboptimal results with PTS patients
      - 50% improved clinical outcome/hemodynamics
- Other
  - Systemic anticoagulation
  - AngioVac cannula & circuit (AngioDynamics)
    - Removes large, soft thrombus (IVC, PE) during up to 6 h extracorporeal bypass

POST PROCEDURE

Things to Do

- **Systemic anticoagulation**
  - Consult appropriate service to advise/manage systemic anticoagulation (e.g., pulmonary, hematology, hospitalist, primary care)
  - Initiate oral systemic anticoagulation next day/before discharge
  - Appropriate systemic anticoagulant
    - Proximal DVT, isolated distal DVT, & PE
      - No cancer: Dabigatran, rivaroxaban, apixaban, edoxaban > vitamin K antagonist > LMWH
      - Cancer associated: LMWH > vitamin K antagonist > dabigatran, rivaroxaban, apixaban, edoxaban
  - Duration: 3 months of anticoagulant therapy

- Proximal DVT provoked by transient risk factor or surgery
- Isolated distal DVT, if anticoagulation required at all
  - ☐ Without severe symptoms/risk factors, hold anticoagulation, image deep veins over 2 weeks; if DVT extends on follow-up imaging, start anticoagulation
  - ☐ Severe symptoms/risk factors exist, anticoagulate
- Recommend 3-month duration > extended therapy

- Duration: 3-month vs. extended duration (no scheduled stop date)
  - Unprovoked DVT or PE, dependent on bleeding risk
  - Cancer-associated, extended therapy, dependent on bleeding risk
- Role of antiplatelet agents remains undefined
  - Aspirin/clopidogrel recommended in some instances if patient refuses anticoagulation
  - Similar regimen as used with arterial disease
    - ☐ Clopidogrel 75 mg daily
    - ☐ Aspirin 81 or 325 mg daily

- Elastic compression stockings (ECS) are no longer recommended
  - SOX trial (2014) (large, double-blind, randomized, multicenter) found no change to PTS rate ± ECS
  - CHEST, 10th Edition no longer recommends use of ECS

OUTCOMES

Problems

- Angioplasty often ineffective as stand-alone therapy for pelvic venous stenoses
  - Venous stenting has better long-term patency

Complications

- Most feared complication(s)
  - Complications related to thrombolysis
    - Hemorrhagic complications (0-17% incidence)
      - ☐ 3.2% major bleed in CaVenT Trial CDT arm
      - ☐ Intracranial/retroperitoneal/GI hemorrhage
    - Symptomatic pulmonary embolus (1%)
      - ☐ Controversy as to IVC filter placement before thrombolysis of large thrombus burden
    - Paradoxical embolus
  - Venous perforation
  - Stent migration/embolization to heart
- Immediate/periprocedural complication(s)
  - Complications of gaining venous access
    - Bleeding/hematoma/nerve injury
  - Acute thrombosis of venous stent(s)
- Delayed complication(s)
  - Neointimal hyperplasia resulting in stent thrombosis
    - Can be treated with secondary intervention(s): Thrombolysis, angioplasty of indwelling stent, additional stent placement

Expected Outcomes

- **Sequela of iliofemoral DVT following > 6 months systemic anticoagulation**
  - At 5 years
    - 95% ambulatory venous HTN
    - 90% CVI
- **Technical success of endovascular thrombolysis**
  - CDT
    - 80-90% success
    - Infusion times variable
  - PMT
    - 82% thrombus removed
    - Shorter infusion time than CDT
  - US-accelerated
    - 91% overall (70% complete) thrombolysis
    - 22-h median infusion time
- **PTS following endovascular thrombolysis**
  - CaVenT trial (2012): Compared occurrence of PTS following DVT conventional treatment ± CDT
    - 6 months after treatment of DVT
      - ☐ PTS in 30-32% of patients (no significant difference between groups)
      - ☐ Patency of iliofemoral vein: 66% in CDT arm, 45% in control arm
    - 24 months after treatment of DVT
      - ☐ 14% absolute risk reduction of PTS following CDT
      - ☐ 7 = number needed to treat to prevent 1 PTS
      - ☐ Quality of life: No differences between groups
  - ATTRACT trial (2017): Compared acute DVT management with systemic anticoagulation ± PMT
    - Study completed; awaiting publication of results
      - ☐ Could modify expected outcomes following PMT

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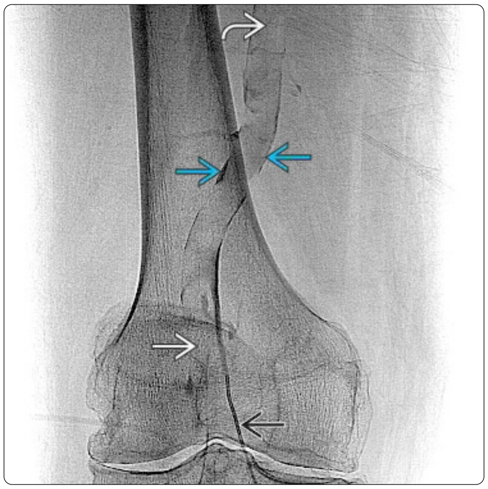
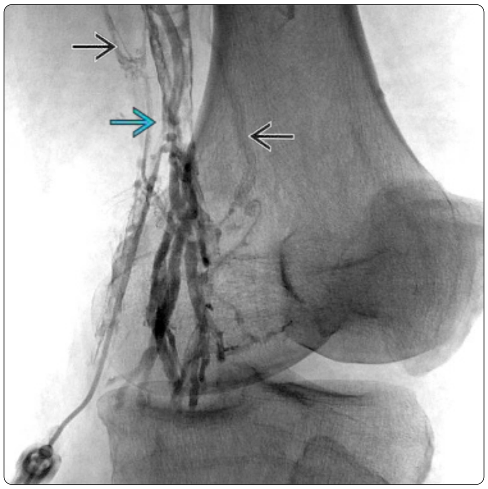
Acute Femoropopliteal DVT

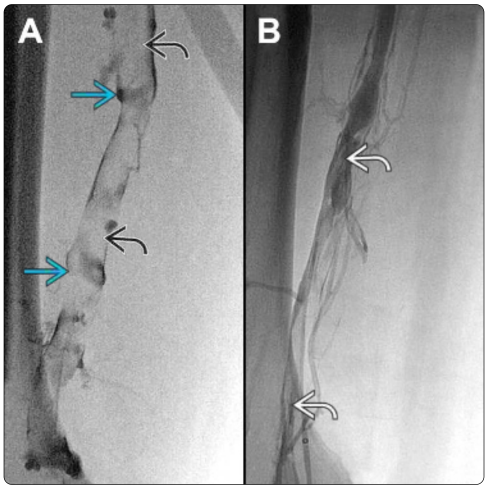


Subacute Femoropopliteal DVT

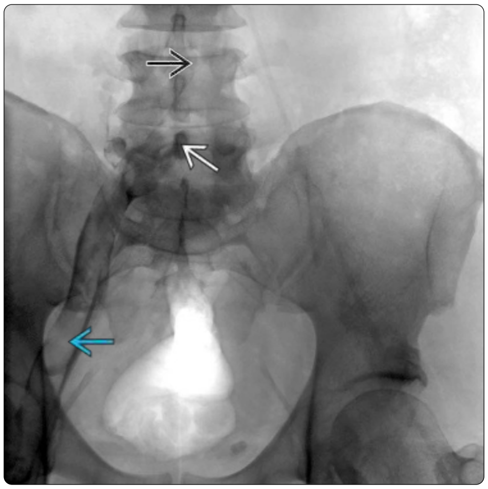


(Left) *Percutaneous access of the popliteal vein* ➡ *has been achieved with a 4-Fr micropuncture sheath* ⇨*. Contrast injected through the sheath outlines the thrombus and circumferentially fills space around it, producing a nearly continuous tram-track appearance* ⇨*, suggesting acuity of the thrombus. Thrombus extends superiorly into the femoral vein* ↪*.* **(Right)** *In contrast, the outline of the thrombus in this popliteal vein is less well defined* ⇨*, and collaterals* ⇨ *are enlarged, suggesting subacuity.*

Acute vs. Chronic DVT

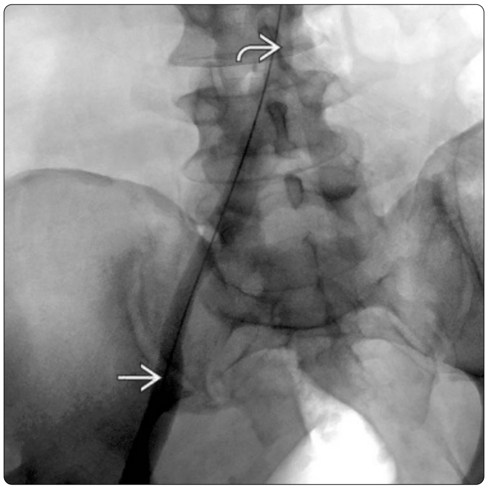


Acute Iliac Vein Thrombosis

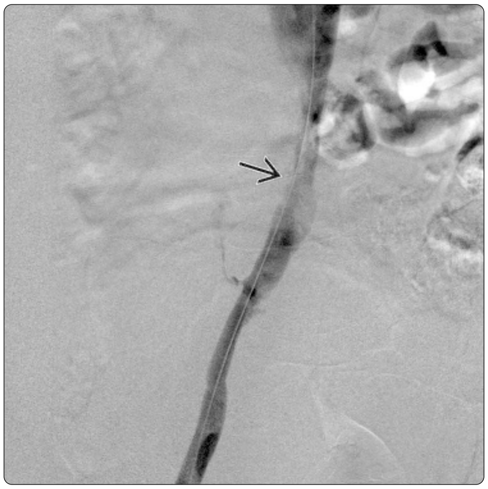


(Left) *Contrast venography shows (A) acute DVT with a well-defined filling defect* ↪ *distending the femoral vein. The outline of the valves is discernible* ⇨*. (B) In chronic DVT, there are extensive linear scars* ↪ *and no demonstrable valves.* **(Right)** *The patient is positioned prone on the fluoroscopy table and contrast is injected through a catheter advanced via the left popliteal vein. Acute thrombus* ⇨ *extends throughout the iliac vein, and no contrast is seen in the IVC* ⇨*, raising concern of right iliac artery compression of the left iliac vein* ➡*.*

Acute Iliac Vein Thrombosis After Catheter-Directed Thrombolysis

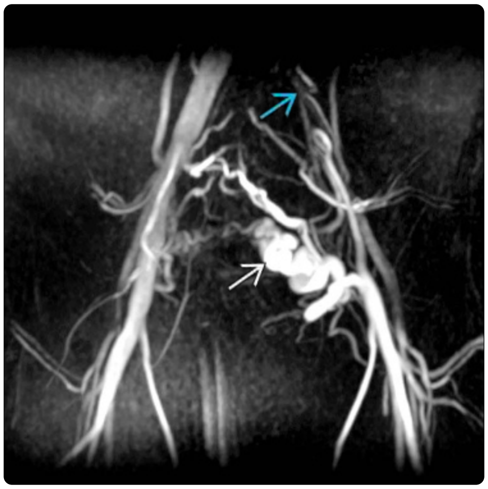


Acute Iliac Vein Thrombosis After Catheter-Directed Thrombolysis

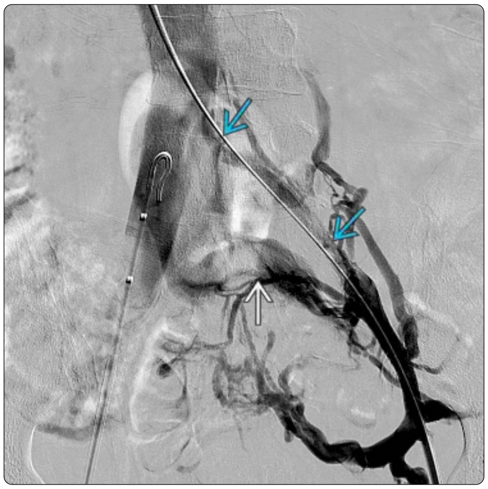


(Left) *Following 20 h of tPA-CDT (in which TPA was delivered at 1 mg/h through an infusion catheter spanning from the inferior extent of the thrombus superiorly into the IVC), venography reveals no remaining filling defects within the patent iliac vein* ➡ *and contrast flowing rapidly into the IVC* ↪*.* **(Right)** *Digital subtraction more clearly displays the left iliac vein/IVC confluence* ⇨*. High-grade stenosis is not apparent, although further evaluation with increased magnification, obliquities, or IVUS may be appropriate.*

(Left) *A 32-year-old woman with left leg swelling and DVT was treated with Xarelto, ultimately resolving the DVT; however, swelling of the left leg remained. A pelvic MRV revealed occlusion of the left iliac* ⇨ *vein and well-formed pelvic collaterals* ➡ *crossing the midline to the contralateral right pelvic veins.* **(Right)** *Bilateral iliac venography shows severe left common iliac vein post thrombotic stenosis* ⇨*, not total occlusion as suggested on the MRV. Varices drain from the left iliac vein to the right internal iliac vein* ➡*.*

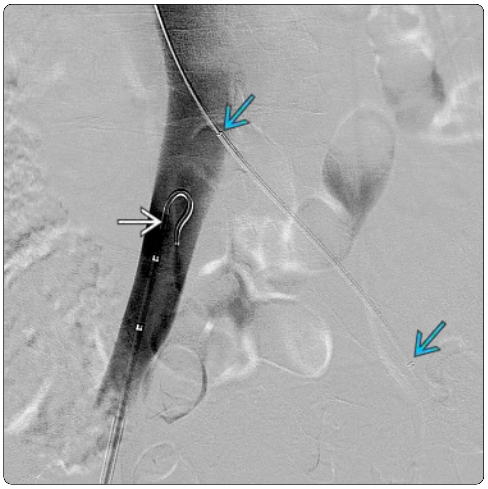


May-Thurner Syndrome (Diagnostic MRV)

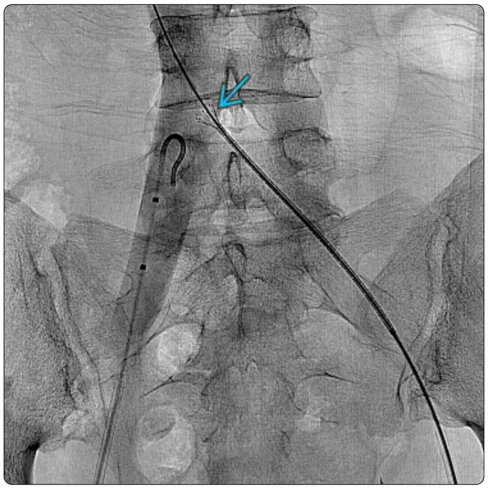


May-Thurner Syndrome (Venography)

(Left) *To restore inline venous return from the left leg, an endovascular stent is advanced across the stenosis* ⇨*. Simultaneous opacification of the IVC is possible due to a flush catheter* ➡ *positioned in the right iliac vein.* **(Right)** *The 14-mm diameter, noncovered, self-expanding stent is partially deployed* ⇨ *as additional venograms ensure the stent extends into the IVC, fully beyond the stenotic segment of vein.*

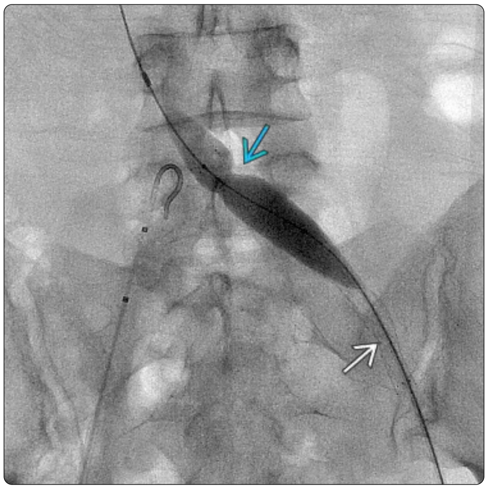


May-Thurner Syndrome (Stent Positioning)

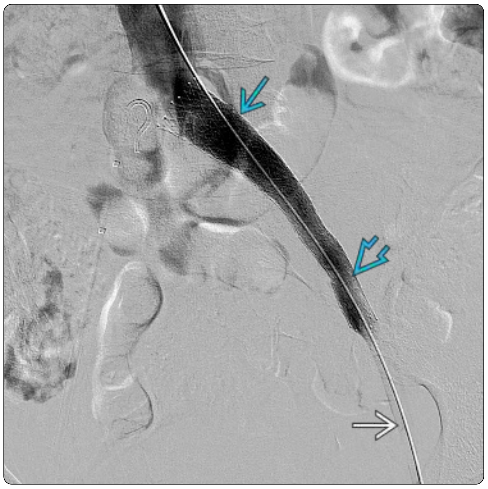


May-Thurner Syndrome (Stent Deployment)

(Left) *Focal narrowing* ⇨ *of this 12-mm diameter angioplasty balloon confirms underlying restrictive scarring of the vessel. Notice further restrictive narrowing of the external iliac vein, preventing full expansion of the stent* ➡ *prior to angioplasty.* **(Right)** *Contrast injection via the left groin sheath* ➡ *shows complete resolution of common iliac vein stenosis* ⇨*. Reflux into collateral veins is not apparent. Residual non-focal, mild narrowing of the left external iliac vein* ⇨ *may require further angioplasty if considered flow restrictive.*

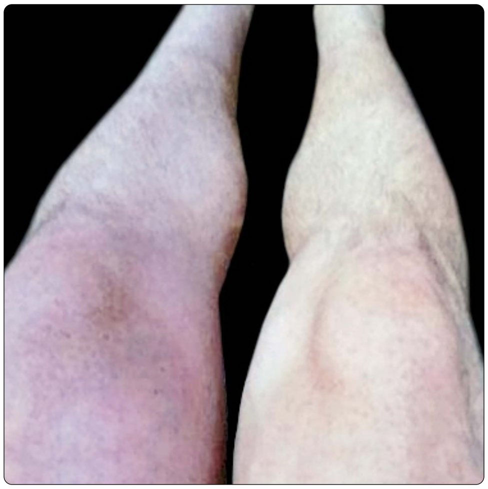


May-Thurner Syndrome (Post Stent Deployment Angioplasty)

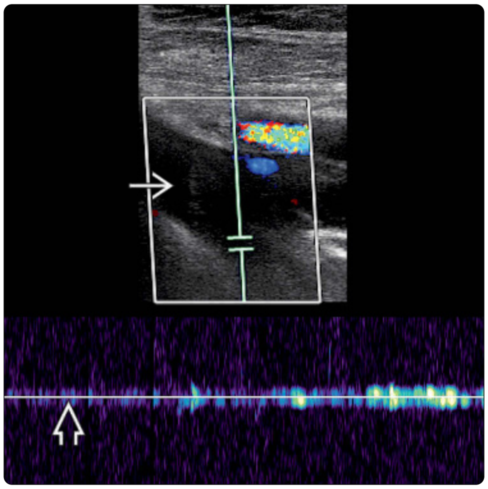


May-Thurner Syndrome (Post Stenting Venogram)

Phlegmasia Cerulea Dolens (Clinical Presentation)

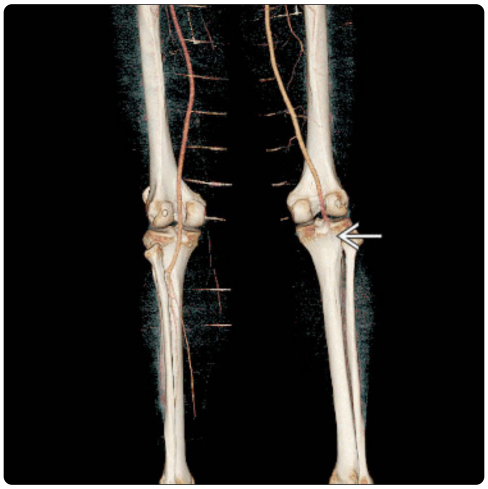


Phlegmasia Cerulea Dolens (CFV Ultrasound)

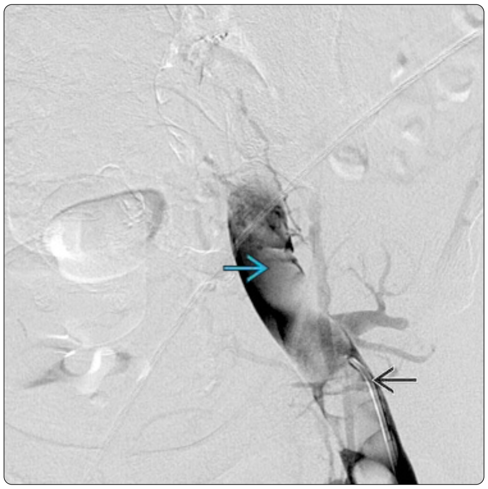


(Left) *A 45-year-old man on a 2-week tour of multiple ballparks, but no other significant prior medical history, presented to ED with a cool, painful, purple left lower extremity (LLE) and hip. LLE pulses were diminished. IV heparin was initiated.* **(Right)** *Color Doppler ultrasound reveals hypoechoic (acute) thrombus ➡, extending from the external iliac vein to the calf veins, and lack of flow on spectral waveform ➡.*

Phlegmasia Cerulea Dolens (CT Angiogram 3D Reconstruction)

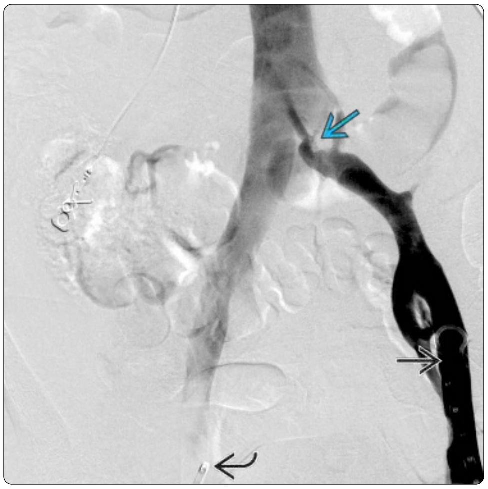


Phlegmasia Cerulea Dolens (Diagnostic Venogram)

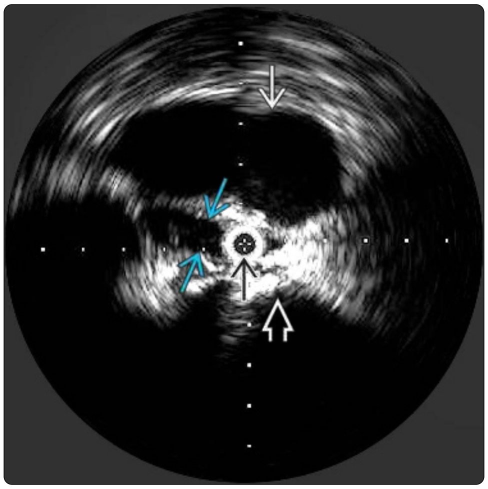


(Left) *CT angiogram, ordered to evaluate diminished LLE pulses, reveals poor opacification of the LLE arteries distal to the popliteal artery ➡, likely due to back pressure from the extensive DVT.* **(Right)** *LLE catheter ⇨ venography shows extensive, occlusive ⇨ thrombus within the dilated left common femoral and iliac veins. The lack of enlarged collaterals suggests acuity. One mg/h TPA-CDT was initiated from the IVC through CFV. (Courtesy N. Saucier, MD.)*

Phlegmasia Cerulea Dolens (Post Thrombolysis)



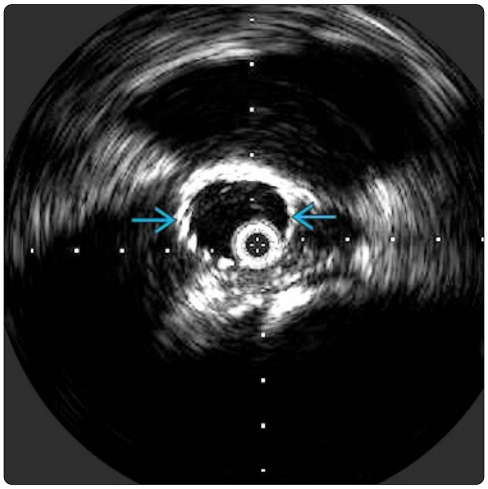
Phlegmasia Cerulea Dolens (IVUS Imaging of Left Iliac Vein)



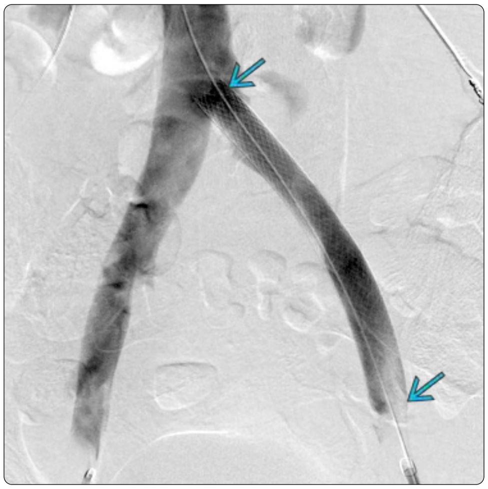
(Left) *After 31 hours of CDT, pelvic venography through a left Omni Flush catheter ⇨ and right sheath ↩ shows complete resolution of pelvic thrombus. High-grade stenosis ⇨ of the left common iliac vein is revealed.* **(Right)** *Circumferential imaging was obtained from an IVUS probe ⇨ advanced through the left iliac vein. Compression of the vein ⇨ is evident between the anterior, obliquely crossing right iliac artery ➡ and posterior vertebral body ➡. (Courtesy J.J. Borsa, MD.)*

(Left) *IVUS can be complementary to fluoroscopic venography when planning and deploying endoluminal stents and may be more sensitive than venography, although the clinical significance of subtle abnormalities found by IVUS remains unclear. In this post deployment image, the stent → is well approximated to the vessel wall, eliminating iliac vein stenosis.* **(Right)** *Pelvic venography confirmed appropriate placement of noncovered Wallstent →. LLE inline flow was restored and swelling resolved.*

Phlegmasia Cerulea Dolens (Post Stent Deployment)

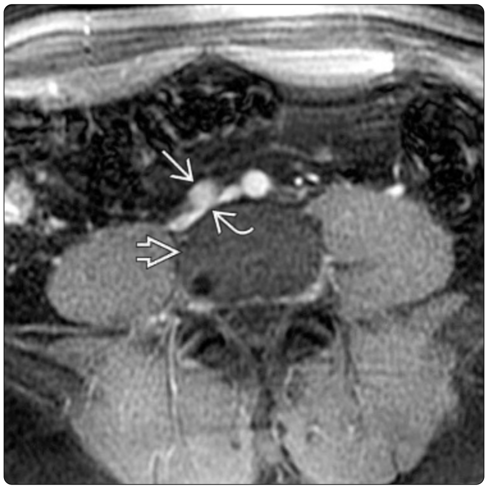


Phlegmasia Cerulea Dolens (Post Stent Deployment)

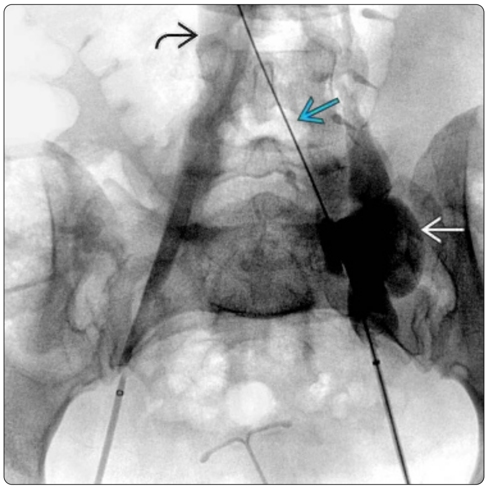


(Left) *Gadolinium-enhanced axial SPGR MR shows severe compression → of the left iliac vein between the right common iliac artery → and lumbar vertebra → in a patient who had severe left leg swelling and acute iliofemoral DVT.* **(Right)** *Venography via bilateral groin sheaths reveals left common iliac vein obstruction → (with crossing wire) resulting in a dilated proximal left common iliac vein drainage through an enlarged collateral →. The right common iliac vein and IVC → are patent.*

May-Thurner Syndrome (Initial MR Imaging)

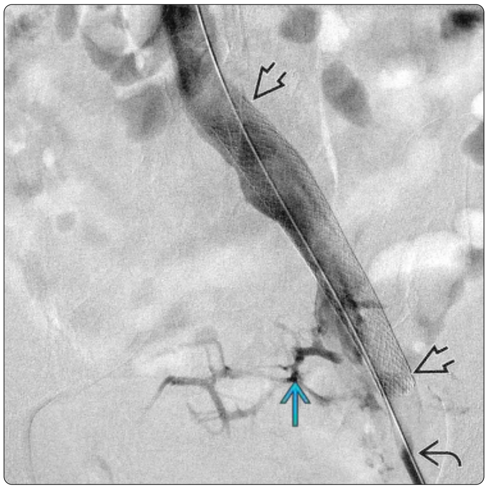


May-Thurner Syndrome (Diagnostic Venography)

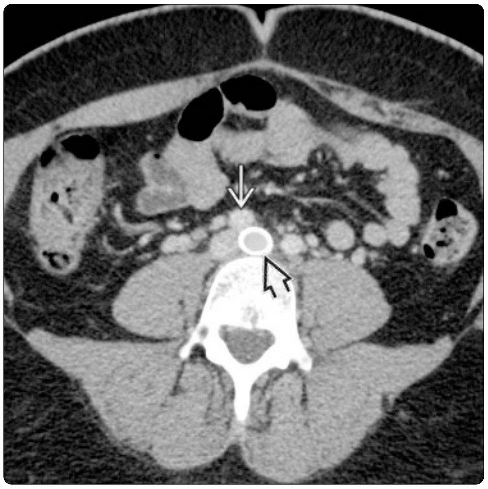


(Left) *Venography via the left femoral sheath → shows the self-expanding stent → in satisfactory position, restoring normal luminal diameter along the course of the common iliac vein. Minimal residual filling of collaterals is to be expected →; however, flow is now preferentially through the stent rather than via the collaterals.* **(Right)** *Three months after intervention, contrast within the stented vessel → confirms patency. The right common femoral artery → is seen anteriorly abutting, but not compressing, the left iliac vein.*

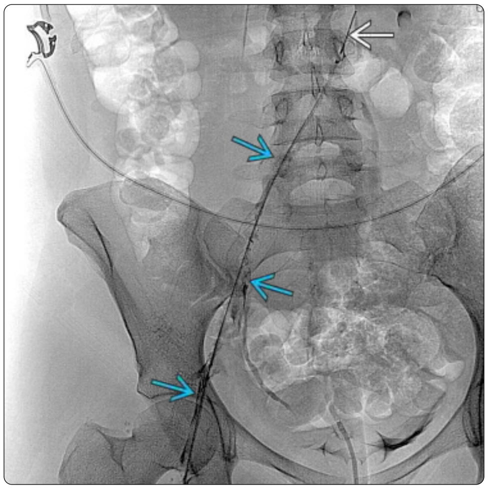
May-Thurner Syndrome (Post Intervention)



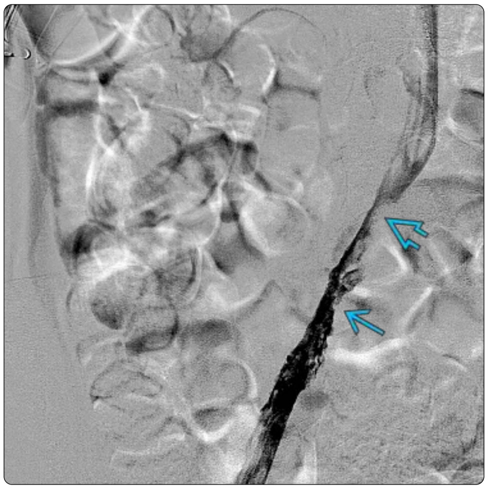
May-Thurner Syndrome (Post Intervention)



Complication of Treatment (Placement of tPA Infusion Catheter)

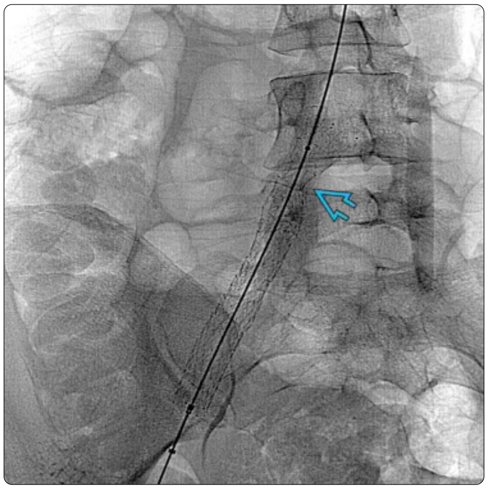


Complication of Treatment (Post tPA Catheter-Directed Thrombolysis)

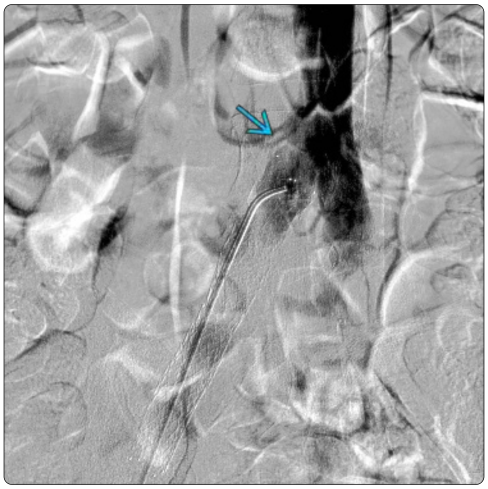


(Left) *A 31-year-old woman with left leg swelling was positioned prone on the fluoroscopy table (patient's left on left of image). Contrast injected through an infusion catheter exits the catheter through innumerable side holes* ⇨*, rather than at the plugged* ➡ *catheter tip, revealing thrombus in various stages of acuity.* **(Right)** *Decreasing fibrinogen forced tPA CDT to be halted after 20 hours. Subsequent DSA showed residual chronic thrombus adherent to the vessel wall* ⇨*, a bulk of which was resembling stenosis* ⇨.

Complication of Treatment (Stent Deployment)

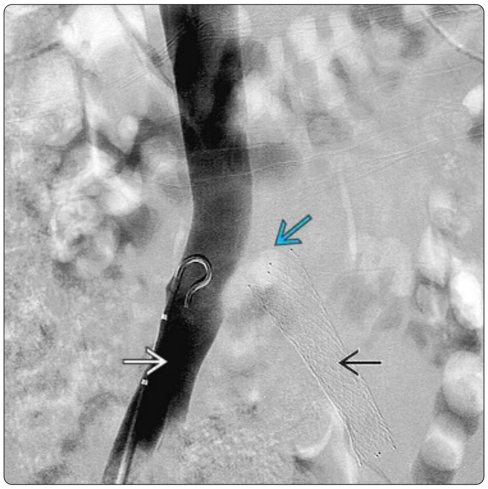


Complication of Treatment (Post Stent Deployment)

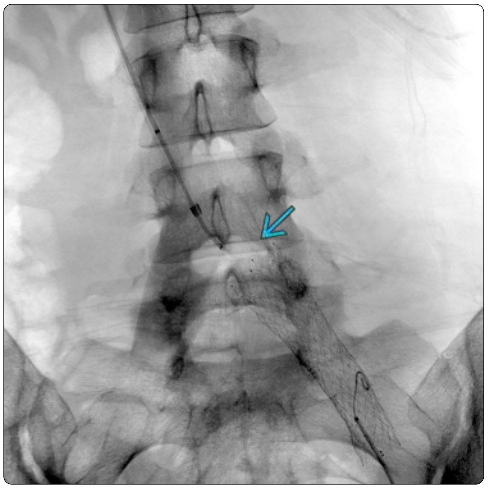


(Left) *A self-expanding, noncovered stent was deployed within the left iliac vein via left popliteal access with the patient prone. Residual narrowing of the stent is consistent with vessel stenosis* ⇨. **(Right)** *DSA catheter venography following stent placement demonstrates rapid flow through the stent and no residual venous stenosis, despite the fact that the stent fails to extend fully into the IVC* ⇨*. Suboptimal image subtraction of bowel somewhat inhibits visualization.*

Complication of Treatment (2-Year Follow-Up)

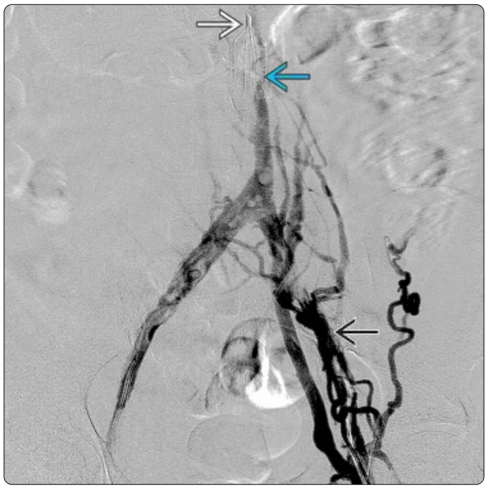


Complication of Treatment (2-Year Follow-Up)

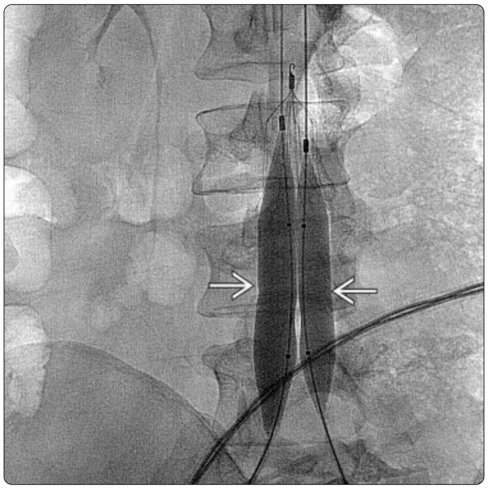


(Left) *Left leg swelling returned 2 years later despite continuous systemic anticoagulation. Contrast injected through a flush catheter in the right iliac vein (with patient supine)* ➡ *shows the left iliac vein stent* ⇨ *discontinuous* ⇨ *from the IVC.* **(Right)** *Intimal hyperplasia and fibrosis* ⇨ *exacerbated by the stent, and continued extrinsic compression from the overlying right iliac artery, thwarted attempts to recanalize the left iliac stent from superior and inferior approaches.*

(Left) *A chronically anticoagulated 31-year-old woman with progressive bilateral lower extremity swelling underwent pelvic venography. Her longstanding IVC filter is properly positioned* ➡*, but severe IVC stenosis* → *at the filter and hypertrophied collateral veins* → *were uncovered.* **(Right)** *Bilateral common femoral vein wires were advanced across the stenosis into the patent suprarenal IVC. Simultaneous PTA was performed in parallel* ➡ *throughout the infrarenal IVC, at, above, and below the filter.*

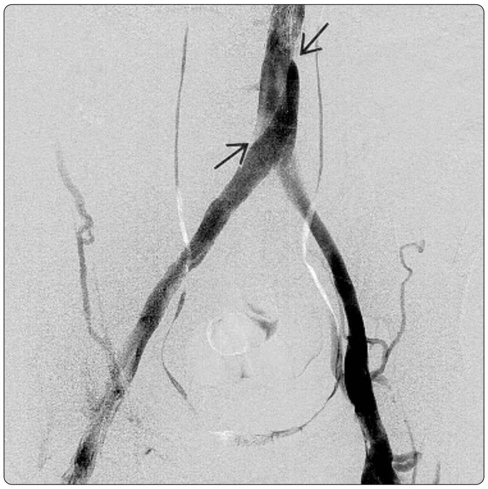


Filter-Related IVC Stenosis (DSA Pelvic Venogram)

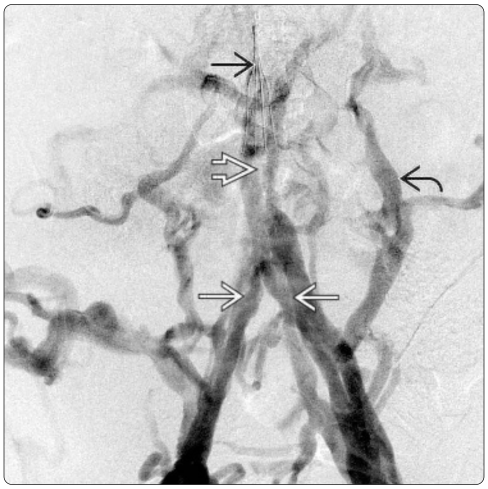


Filter-Related IVC Stenosis (Recanalization and Angioplasty)

(Left) *Following PTA, pelvic venography via bilateral CFV access sheaths shows flow markedly improved through the IVC, although a linear oblique-running web remained* →*. Since collateral filling was significantly decreased, no stenting was performed at this time.* **(Right)** *Venography via 2 femoral venous sheaths shows patent common iliac veins with synechiae* ➡*. The infrarenal IVC* ⇨ *is almost completely thrombosed below the filter* → *with preferential venous return via enlarged collaterals* ↪*.*

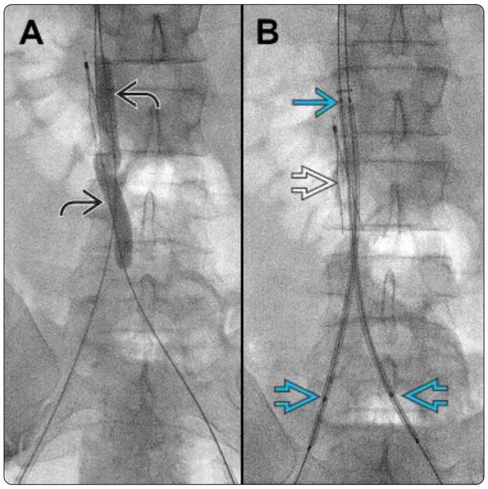


Filter-Related IVC Occlusion (Post Angioplasty DSA Pelvic Venogram)

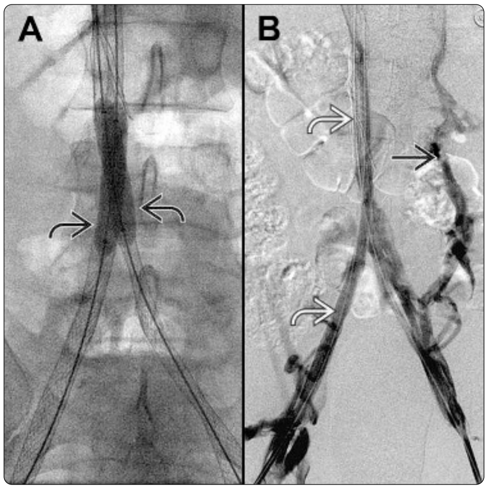


IVC Stenting Across Filter (Diagnostic Venogram)

(Left) *(A) Guidewires were advanced through the IVC and simultaneous angioplasty* ↪ *was performed at and below the filter to create lumina for stenting. (B) Bilateral Wallstents* ⇨ *have been introduced but are not yet deployed. The proximal ends* → *extend just superior to the IVC filter* ⇨*.* **(Right)** *(A) After deploying "kissing" self-expanding stents, balloon dilation* ↪ *is performed, especially important at the filter to create an adequate lumen. (B) DSA after stenting shows flow via both stents* ↪ *and collaterals* →*.*

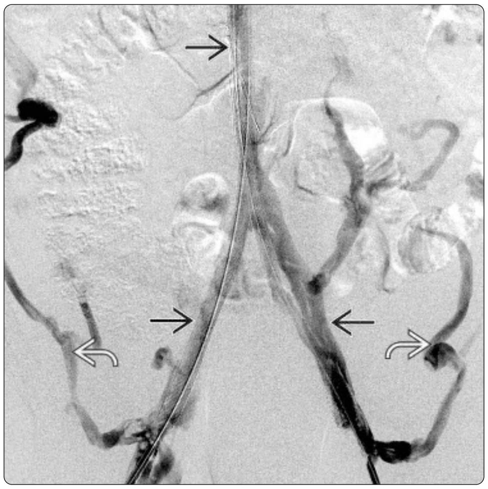


IVC Stenting Across Filter (Angioplasty and Stent Positioning)

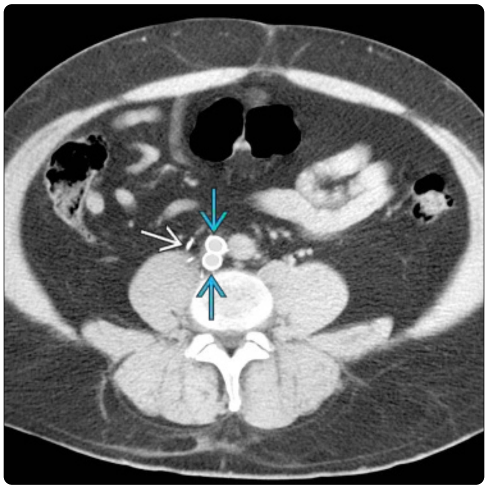


IVC Thrombosis Management (Venous Angioplasty and Stenting)

IVC Thrombosis Management (Post Intervention DSA Venogram)

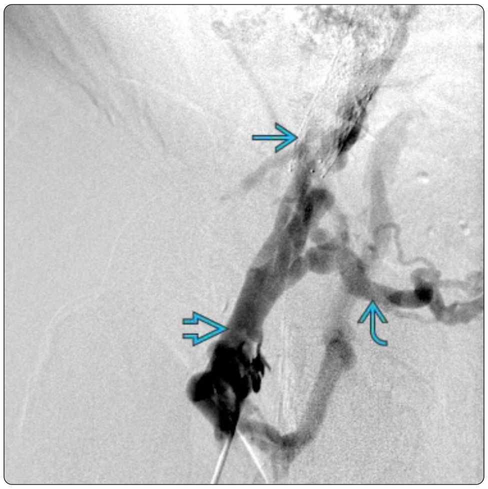


IVC Thrombosis Management (Follow-Up Abdominal CECT)

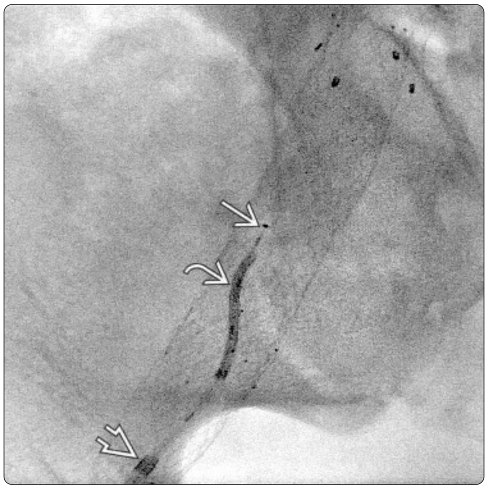


(Left) *Following further stent-expanding angioplasty, both stents are patent →, although venous return continues via the well-developed venous collaterals ↪. The patient was discharged on warfarin and was symptomatically improved on follow-up.* **(Right)** *Venous phase axial CECT obtained at 3-month follow-up shows contrast within parallel iliocaval Wallstents →, indicating patency. Tines → from the displaced IVC filter are incidentally noted to have penetrated cava.*

Advanced Recanalization of In-Stent Occlusion (CFV DSA)

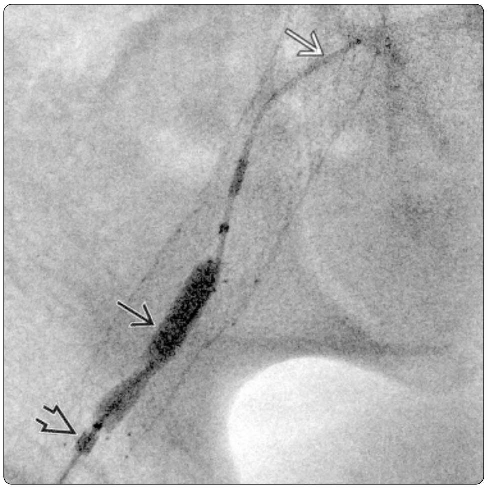


Advanced Recanalization of In-Stent Occlusion (Radiofrequency Wire)

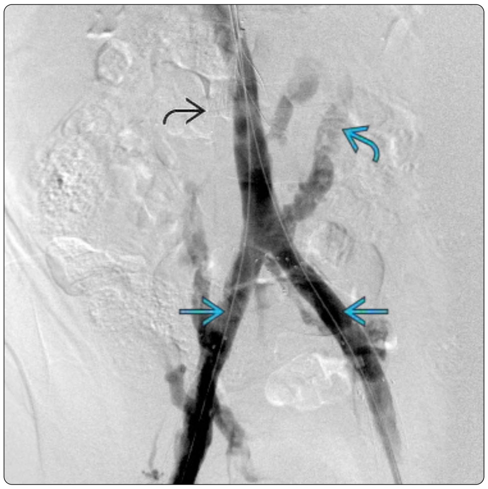


(Left) *Right CFV ⇨ DSA was performed on a 30-year-old woman with recurrent lower extremity swelling 2 years after placement of bilateral iliac vein stents. The right external iliac stent → is occluded and pelvic venous collaterals ↪ are hypertrophied.* **(Right)** *Coaxial advancement of a 6-Fr sheath ⇨, angled catheters ↪, and hydrophilic wires (including firm advancement of the back of wires) failed to cross the in-stent occlusion. Ultimately, a RF wire (Baylis Medical) → was tried.*

Advanced Recanalization of In-Stent Occlusion (In-Stent Angioplasty)



Advanced Recanalization of In-Stent Occlusion (Bilateral Pelvic DS Venogram)



(Left) *The RF wire advanced several cm (under constant fluoroscopic visualization in multiple obliquities) and was exchanged for a stiff guidewire →. Angioplasty (5 mm) → enlarged the channel until the access sheath ⇨ could advance.* **(Right)** *By alternating RF wire advancement and angioplasty, both iliac veins → were recanalized and inline flow restored. Note continued filling of collateral veins ↪ and protrusion of the IVC filter tines ↪. Unfortunately, in-stent reocclusion is likely.*

Vena Cava Filter Placement and Retrieval

KEY FACTS

TERMINOLOGY

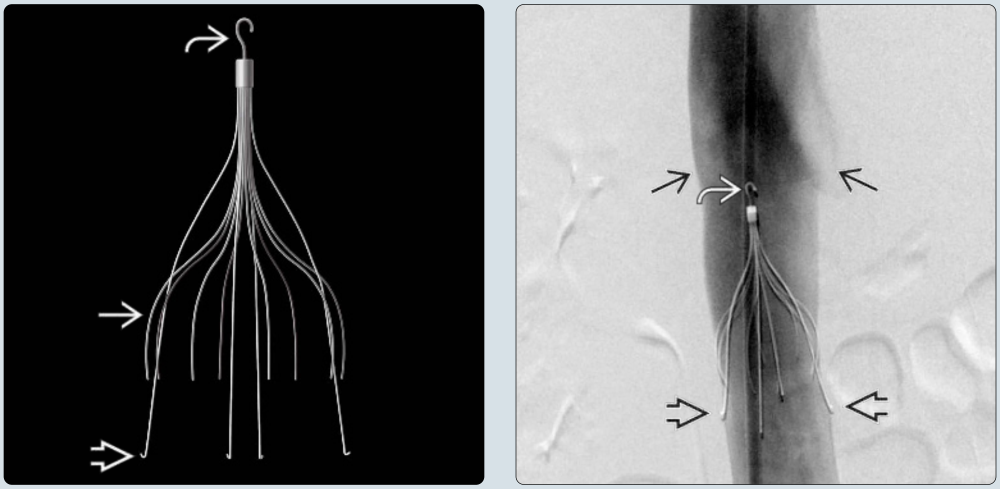
- VCF: Medical device percutaneously placed in vena cava
  - Designed to mechanically trap pulmonary emboli
  - Mechanical prophylaxis for pulmonary emboli
- Permanent filters: Long-term contraindication to anticoagulation
- Nonpermanent filters: Optional (retrievable/convertible) and temporary

PREPROCEDURE

- Filter indications in presence of venous thromboembolic (VTE) disease
  - Contraindication for anticoagulation
  - Failure of anticoagulation
  - Complication of anticoagulation
- Filter indications in absence of VTE disease
  - High VTE risk; anticoagulation not possible
- VCF removal/discontinuation indication
  - No further indication for caval interruption
    - No further contraindication to anticoagulation
    - No increased risk for VTE
- Anatomical location of filters
  - Infrarenal inferior vena cava (IVC): Ideal location
  - Suprarenal IVC: Pregnancy, anatomic variants, IVC compression, thrombus in gonadal/renal veins

PROCEDURE

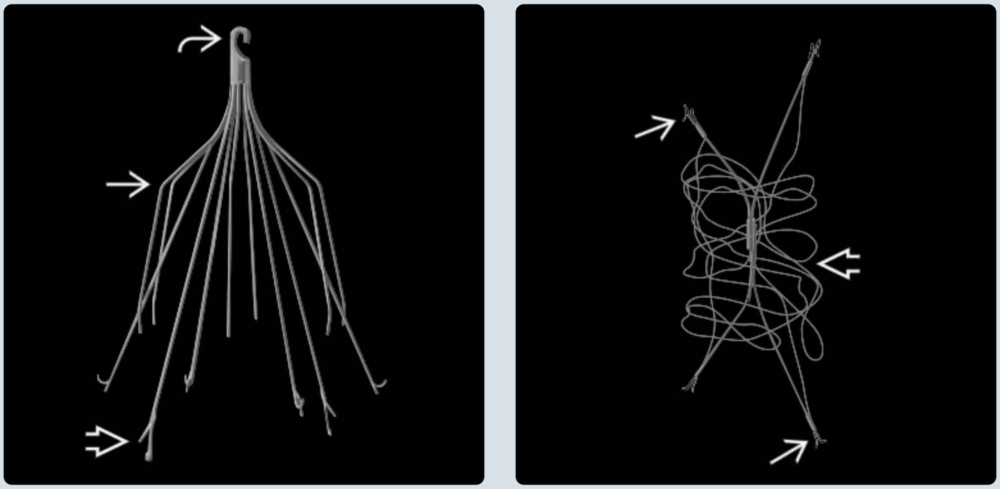
- VCF placement
  - Perform DSA contrast venacavography
    - Identify renal vein levels and confirm IVC diameter
  - May use IVUS or CO_2 venography if necessary
  - Introduce and deploy VCF
- VCF removal
  - Perform vena cavogram
  - If apex free of caval wall, may use snare or cone for retrieval
  - If filter tilted or apex tethered to caval wall, removal may require more advanced techniques



Nonpermanent Filter

Nonpermanent Filter: Proper Placement

(Left) *Photo of a Cook Celect retrievable vena cava filter (VCF) demonstrates the conical, self-centering design ➡ with retrieval hook ↪ at the apex and anchors ⇨ on the lower legs.* **(Right)** *DSA shows the radiographic appearance of a Celect filter after insertion. The filter is centered, without tilt. The filter apex and retrieval hook ↪ are near the inflow level of the renal veins →. Anchors ⇨ at the end of each strut prevent filter migration.*



Nonpermanent Filter

Permanent Filter

(Left) *The Denali vena cava filter has a similar design to the Celect filter, except, the self-centering legs are more angulated ➡ and the legs and retrieval hook ↪ are all cut from 1 piece of nitinol. Note similar anchors ⇨ to help prevent filter migration.* **(Right)** *The Bird's Nest permanent filter has a vastly different design intended for placement in megacavas > 30 mm in diameter. This filter has 2 V-shaped struts ➡ that support a random tangle of smaller wires ⇨.*

TERMINOLOGY

Abbreviations

- Vena cava filter (VCF)

Definitions

- **VCF**: Endovascular medical device implanted percutaneously in vena cava
    - Designed to mechanically trap venous emboli
    - Mechanical prophylaxis for pulmonary embolus (PE)
    - Multiple indications for placement
- **Permanent filter**: Designed for permanent caval interruption
    - Indicated for long-term contraindication to anticoagulation
    - Not designed/approved for retrieval
        - Increasingly fewer insertions; nonpermanent filters preferred
    - Multiple proprietary designs
        - Gianturco-Roehm Bird's Nest (Cook Medical; Bloomington, IN)
            - V-shaped struts support random tangle of wires
            - May place in inferior vena cava (IVC) with diameters of up to 40 mm
            - Produces marked MR susceptibility artifacts
        - Greenfield (Boston Scientific; Natick, MA)
            - Cone-shaped design; can fill 70-80% of device with clot without affecting IVC blood flow
            - Titanium and over-the-wire (OTW) configurations
        - Simon Nitinol (Bard; Covington, GA)
            - 2-level filter design: Upper level cone-shape/lower level self-centering legs
            - Produces minimal MR artifact
        - TrapEase (Cordis; Bridgewater, NJ)
            - Nitinol; self-centering double-basket design
            - Approved for IVC diameters of up to 30 mm
        - Vena Tech (B. Braun; Bethlehem, PA)
            - Made from Phynox: Nonferromagnetic alloy; excellent MR compatibility
            - Conical design; 6 longitudinal anchoring side rails to improve device centering
- **Nonpermanent filter**: Designed for temporary caval interruption
    - Retrievable (optional) filters
        - Designed for removal after risk of PE resolved
        - Can remain permanently: < 50% of filters removed
        - Retrievability period: Variable (device specific)
        - Short-term contraindication for anticoagulation
    - Temporary filters
        - Not designed for permanent placement
        - Must remove before filter/tether adheres to IVC
        - Not available in USA
    - Convertible (optional) filters
        - Permanent device that can be structurally altered to no longer function as filter
        - If not converted, provides permanent protection
    - Available nonpermanent filters
        - Crux Vena Cava Filter System (Volcano; San Diego, CA)
            - Self-centering, no tilt spiral design
            - Caudal and cephalad retrieval hooks
            - Allows jugular or femoral placement (and retrieval)
        - Denali (Bard; Covington, GA)
            - 2 levels of filtration: 6 primary legs with anchors, 6 secondary legs
            - Conical self-centering design with retrieval hook at apex
            - Previous iterations no longer available (e.g., G-2, Meridian, Eclipse)
        - Günther Tulip (Cook Medical; Bloomington, IN)
            - Conical design with retrieval hook at apex
            - 4 primary legs with anchors
            - Each primary leg has 2 secondary legs for filtration/stabilization
        - Celect (Cook Medical; Bloomington, IN)
            - Conical design with retrieval hook at apex
            - Upper self-centering tier/lower tier hooks
        - Option ELITE (Angiotech; Vancouver, BC)
            - Conical design with retrieval hook at apex; 6 struts with anchors
            - 5-Fr internal diameter delivery sheath
            - May be placed via popliteal or antecubital veins
            - OTW placement for stability and precise placement
        - OptEase (Cordis; Bridgewater, NJ)
            - Similar to TrapEase; caudal retrieval hook
        - SafeFlo (Rafael Medical; Dover, DE)
            - Nitinol double-ring anchoring mechanism; alternative to strut-based filter designs
            - FDA approval only for permanent insertion; European approval as retrievable
- Anatomical filter placement locations/indications
    - **Infrarenal IVC**: Ideal/preferred VCF location
        - Normal IVC and renal veins
            - Immediately below lowest renal vein level
        - Circumaortic left renal vein
            - Place filter below this level or suprarenal
    - **Suprarenal IVC**: Location indicated when infrarenal VCF placement problematic
        - Anatomic variants
            - Duplicated infrarenal IVC (1-2% incidence): Left IVC drains into normal left renal vein; joins right IVC; forms single normal suprarenal IVC
            - Left IVC (0.5% incidence): IVC enters left renal vein; courses right to form single normal suprarenal IVC
            - Low insertion of renal veins
        - Pregnancy
        - Thrombus in IVC/gonadal/renal veins
        - Pelvic mass compressing infrarenal IVC
        - Presurgical placement followed by surgery in which IVC manipulation may occur
    - **Bilateral common iliac veins**: Alternative location to suprarenal IVC filter placement
        - Anatomic variants
            - Duplicated IVC
            - Low insertion of renal veins
            - Megacava
        - Surgery in which IVC manipulation may occur
    - **Superior vena cava (SVC):** May be considered for upper extremity deep venous thrombosis (DVT)
        - Not routinely done

    - Literature suggests benefit in select subgroup of patients
    - Unique risks include
      - SVC thrombosis
      - Migration to heart (closer)
      - SVC perforation
- **Intravascular ultrasound (IVUS)**: Specially designed catheter; miniaturized distal US probe
  - Provides 360° intravascular field of view
    - Visualizes endothelium, venous confluences
    - Adjacent arterial/venous structures visualized
  - Provides image guidance if cannot use fluoroscopy
    - Bedside IVC filter placement
    - Contraindication to contrast

PREPROCEDURE

Indications

- In presence of venous thromboembolic (VTE) disease
  - Contraindication to anticoagulation
    - Active bleeding
    - Intracranial neoplasm
    - Hemorrhagic stroke
    - Recent major surgery
    - Bleeding diathesis
    - Fall risk
  - Complication of anticoagulation
  - Failure of anticoagulation
    - Recurrent symptomatic PE or propagation/progression of DVT despite therapeutic anticoagulation
    - Inability to maintain adequate anticoagulation
  - Significant cardiopulmonary disease; hemodynamically unstable
    - Adjunct to anticoagulation
  - Perioperative patients with recent history of VTE for whom anticoagulation must be interrupted
  - Mobile iliocaval thrombus
    - Endorsed by Society of Interventional Radiology (SIR) and American College of Radiology (ACR)
    - Limited data to support benefit
  - Massive PE treated with thrombolysis or thrombectomy or during thromboendarterectomy
    - Endorsed by SIR, ACR, American College of Chest Physicians (ACCP); opposed by American Heart Association (AHA)
- In absence of VTE disease
  - Prophylaxis in patients at high risk for VTE; anticoagulation not possible
    - Severe trauma
      - High-risk injuries: Cranial, severe pelvic/long bone fractures, spinal injury with deficit
    - Intracranial hemorrhage
    - Following high-risk surgical procedures
      - Limited ambulation/mobility increases VTE risk
    - Endorsed by SIR, ACR; opposed by ACCP
- Filter removal/discontinuation of filtration
  - Indications
    - No further contraindication to anticoagulation
    - Permanent VCF unnecessary
    - Acceptably low risk of clinically significant PE
    - No anticipation of return to high-risk status for PE
    - Sufficient life expectancy for removal benefits
    - Filter can be safely removed/converted
  - Benefits
    - Eliminates risk of filter-associated IVC thrombosis/DVT
      - Increased risk with indwelling IVC filter
    - Eliminates risk of filter migration/fragmentation
  - Safe removal period determined by manufacturer
    - Often can be removed safely long after manufacturer's removal period

Contraindications

- Complete occlusion/atresia/absence of IVC
  - Venous return via collaterals
    - Unlikely route for PE
- Lack of venous access site
- Severe uncorrectable coagulopathy
- Bacteremia or untreated infection

Preprocedure Imaging

- Review if available; may diagnose major venous abnormalities/variants
  - CTA or CTV/MRV
    - Evaluation for variant venous anatomy
      - IVC atresia/duplication
      - Circumaortic left renal vein
      - Megacava
    - Evaluation for venous patency
      - Exclude/confirm thrombosis or occlusion
  - US/duplex
    - Evaluate extent of DVT if present
    - Determine venous access site for VCF placement

Getting Started

- Things to check
  - Pertinent clinical history and physical examination
    - Procedure indications
    - Patency of planned venous access site
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - Complete blood count
      - Platelet count > 50,000/µL
    - Coagulation profile
      - International normalized ratio ≤ 2.0
  - Contraindication to contrast media
    - May require imaging guidance with IVUS or CO_2 venography
  - Hemodynamically unstable patients/ICU
    - Consider bedside VCF placement with IVUS
  - Procedural informed consent
- Medications
  - Local anesthetic: 1-2% lidocaine
  - Stop intravenous heparin 1 hour before procedure
- Equipment list
  - General
    - 19-g needle or micropuncture access set
    - 0.035" guidewire

    - Filter and delivery system kit (proprietary)
  - Fluoroscopic guidance
    - Fluoroscopy/angiographic equipment
  - IVUS guidance
    - IVUS probe/catheter
      - Inserted via 8-Fr vascular access sheath
  - VCF retrieval
    - Appropriately sized vascular access sheath
    - Filter retrieval kit (proprietary)
      - Günther Tulip VCF retrieval set (Cook Medical; Bloomington, IN)
      - Recovery Cone removal system (Bard; Covington, GA)
      - Amplatz GooseNeck snare (Covidien; Mansfield, MA)
      - Bard Snare Retrieval Kit (Bard; Covington, GA)
    - Ancillary materials for difficult retrievals
      - Tip-deflecting guidewire
      - Angioplasty (PTA) balloon(s)
      - Endobronchial biopsy forceps
      - Complex curve catheters

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Transjugular approach
    - Indications
      - Bilateral femoral/iliac DVT
      - Outpatient; less hematoma risk
      - Large pelvic mass, pregnancy
  - Transfemoral approach
    - Indications
      - Preferred in IVUS placement
      - Poor/occluded jugular access
    - Right femoral approach preferred
      - Straighter path for filter delivery than left
  - Often based on personal preference

Procedure Steps

- **Fluoroscopic guidance**
  - Access vein and place vascular sheath
    - May use transjugular or transfemoral access
  - Introduce flush catheter and sheath over 0.035" guidewire
    - Position in IVC just above iliac venous confluence
  - Perform contrast venacavography
    - 20-30 mL volume; flow rate of 15-20 mL/s
    - May also use CO_2 if contraindication to iodinated contrast
  - Evaluate IVC and renal veins
    - Diameter of IVC
      - Most filters sized for IVC diameter < 28-30 mm
      - Megacava: IVC diameter > 30 mm
    - Thrombosis of IVC
    - Location, number, and origin of renal veins
    - Anatomic variants
    - Extrinsic compression, tumor invasion
  - Exchange catheter for filter delivery system
  - Deploy filter based on manufacturer's instructions for use and IVC/renal vein anatomy
    - Normal IVC/renal vein anatomy: Infrarenal VCF
      - Position filter apex at or just below renal vein level
    - If infrarenal VCF placement problematic
      - Determine if suprarenal IVC vs. bilateral common iliac vein filters more appropriate
    - Megacava: Bilateral common iliac filters or Gianturco-Roehm Bird's Nest filter
  - Perform postfilter placement cavography or KUB
    - Document filter position, including angulation/tilting
  - Remove vascular sheath
  - Obtain hemostasis with manual compression
- **IVUS guidance**
  - Obtain transfemoral access with 19-g needle
  - Introduce 0.035" guidewire
  - Place 8-Fr short vascular sheath
  - Introduce IVUS catheter over guidewire
  - Advance IVUS catheter to right atrial level
  - Perform pull-back IVUS mapping
    - Determine level of renal veins
      - Right renal artery crosses IVC anteriorly at renal vein level
      - IVC becomes elliptical at renal vein level
    - Determine level of iliac vein confluence
  - **Single venous access technique**
    - Determine distance to lowest renal vein with IVUS
    - Mark IVUS catheter with Steri-strips at sheath hub
      - Remove IVUS catheter over guidewire
    - Measure IVUS catheter tip to Steri-strip distance
    - Mark VCF delivery sheath to same distance
    - Advance VCF delivery system over guidewire
    - Deploy according to instructions for use
    - Remove delivery sheath/access sheath
    - Obtain hemostasis with manual compression
    - Obtain abdominal radiograph
      - Confirm filter position
  - **Dual venous access technique**
    - Perform IVUS mapping via femoral access sheath
    - Obtain 2nd femoral vein access or jugular access
      - Use to introduce VCF delivery system
    - Deploy VCF during real-time IVUS imaging
  - Completion same as single venous access technique
- **Fluoroscopic guidance without contrast**
  - If contrast contraindication and IVUS unavailable
  - Determine appropriate placement level based on CT
  - Catheterize each renal vein using Cobra-1 catheter
    - Mark renal vein levels relative to bone landmarks
    - Deploy filter based on landmarks
- **Filter retrieval**
  - Access route
    - Jugular vein access for most retrievable filters
    - Femoral vein access for OptEase filter retrieval
    - Jugular or femoral vein access for Crux filter
  - Place appropriate diameter and length vascular sheath
    - Often included with retrieval system
  - Perform DSA venacavography
    - Assess for thrombus, position of filter/legs
  - **If thrombus present**

- Significant thrombus contraindication to retrieval
  - Anticoagulation course indicated
- Small foci of thrombus may not preclude retrieval
- **If no thrombus and VCF centered in IVC**
  - Introduce appropriate VCF retrieval device
  - Snare retrieval hook of filter
  - Use sheath to collapse filter legs
    - Collapse rather than pull filter into sheath
    - Limits injury to caval wall
- **If VCF tilted/embedded in IVC wall**
  - Free apex of VCF from caval wall
    - Use tip-deflecting wire/reverse curve catheter
    - Inflate PTA balloon between VCF and IVC wall
    - Inflate PTA balloon inside VCF; apply traction
    - Use endobronchial forceps to dissect endothelium from VCF, grasp apex
  - Once centered, use snare to engage hook
    - May use endobronchial forceps or retrieval cone
  - Advance sheath over VCF and remove
- Perform DSA venacavogram through sheath after retrieval
  - Document appearance of IVC
    - Evaluate for stenosis, irregularity, or extravasation
- May consider brief anticoagulation period

Alternative Procedures/Therapies

- Surgical
  - IVC interruption: High incidence of IVC thrombosis
    - Ligation, clipping, plication, stapling
- Other
  - Systemic anticoagulation for treatment of VTE

POST PROCEDURE

Things to Do

- Clinically follow optional filter patients
  - Contact patient as needed for retrieval
  - Prompt retrieval when indicated improves retrieval rates and decreases complications
    - Window of retrievability varies by device
  - May leave filter permanently if clinically indicated
- Interventionalist should be actively involved in follow-up care to increase rate of successful retrieval and minimize complications

OUTCOMES

Complications

- Most feared complication(s)
  - Filter migration (1-3% incidence)
    - May embolize to right atrium/ventricle
      - Operator error most common cause
      - Other causes: Megacava, device fracture
      - 45% reported mortality if filter remains in heart
  - Filter fracture/penetration by components
    - Fractured components may embolize
      - Potential for life-threatening sequelae
    - Filter penetration may be symptomatic
      - Irritation of adjacent structures by penetration
- Immediate/periprocedural complication(s)
  - Contrast media issues (allergy/nephropathy)
  - Arrhythmia, air embolism
    - Most common with jugular approach
  - Filter deployment issues
    - Incomplete delivery
    - Incomplete opening of device
    - Excessive tilting
      - Not protective against PE
      - May reposition or place 2nd filter
    - Misplaced filter: Common iliac veins
  - Thrombosis of venous access site (up to 6%)
  - PE
  - Pneumothorax
- Delayed complication(s)
  - Increased risk of subsequent DVT
  - PE (1-5%) (permanent filters)
  - Migration (5-27%) (permanent filters)
    - > 2 cm filter position change from initial
  - Filter penetration outside IVC
    - May penetrate aorta, bowel, bone, adjacent organs
      - Typically clinically insignificant
    - Reported incidence as high as 40-95%
      - More likely longer filter is in place
  - Filter fracture
- Other complications
  - IVC thrombosis (2-30%)
    - May be asymptomatic
    - May cause massive lower extremity swelling

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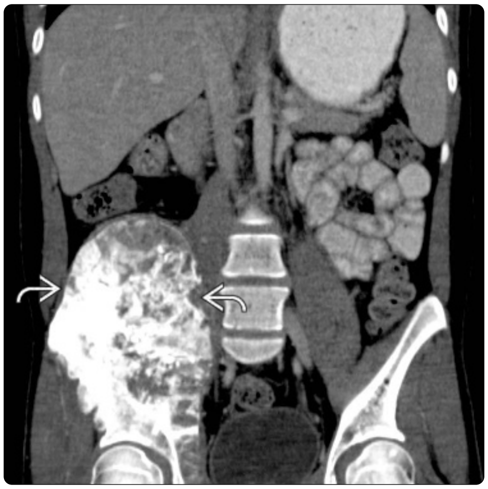
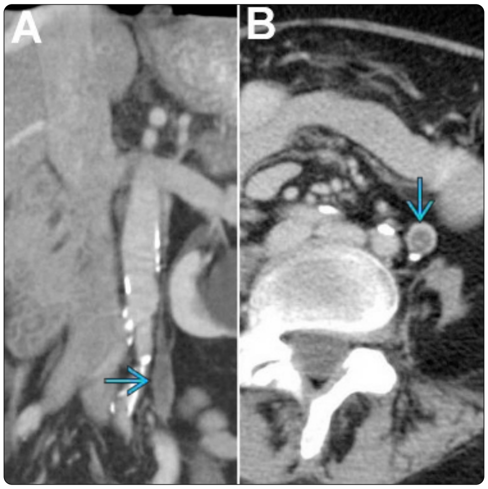
Preprocedural Planning: Filter Position

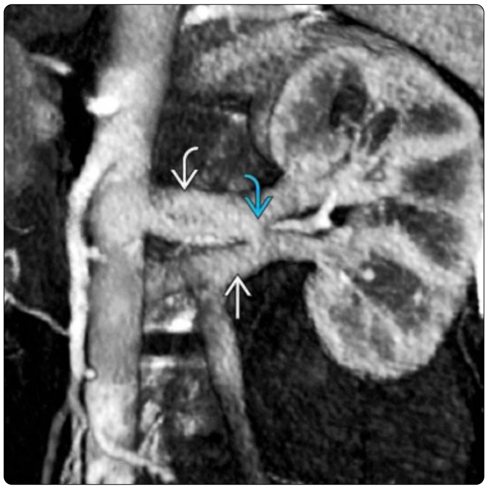


Preprocedural Imaging: Filter Position

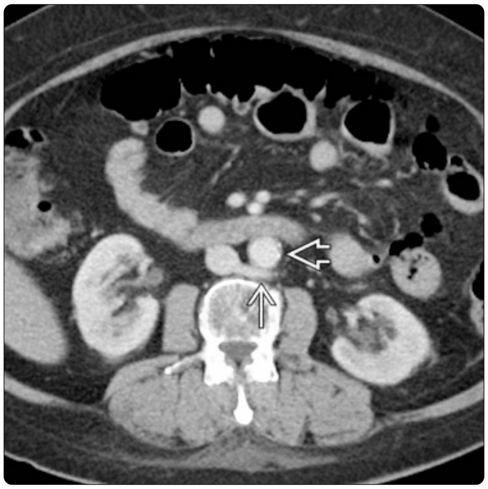


(Left) *CT shows osteosarcoma ➦ scheduled for resection. Prophylactic preoperative temporary VCF insertion was needed because of subsequent lengthy immobility. If there will be inferior vena cava (IVC) manipulation during surgery, this will influence the optimal filter position.* **(Right)** *Coronal (A) and axial (B) CECTs from a female with documented pulmonary embolus and an anticoagulation contraindication show a filling defect ⇨ in the left ovarian vein, consistent with thrombus. Suprarenal VCF placement may be indicated.*

Preprocedural Planning: Variant Anatomy

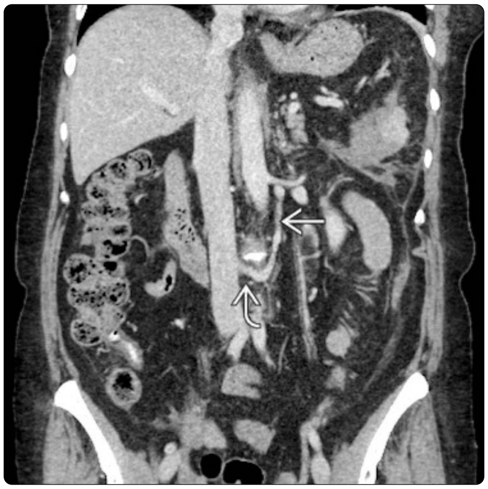


Preprocedural Planning: Variant Anatomy

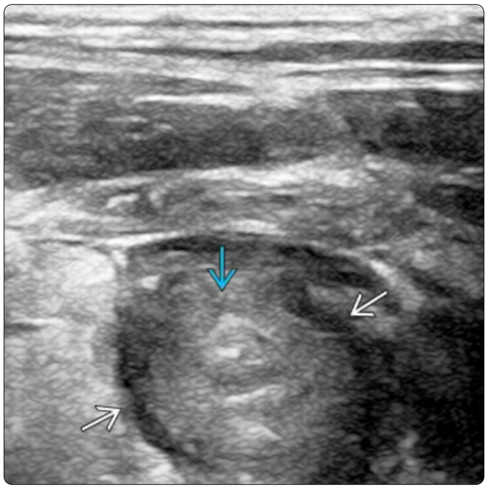


(Left) *A circumaortic left renal vein is shown. There are typically horizontally (or inferiorly) directed ➦ and superiorly directed ➡ main renal venous trunks. Intravenous communications ⇨ provide a potential route for thromboemboli to the lungs if a VCF is placed below the upper venous moiety.* **(Right)** *Review of axial imaging (same patient) identified the left renal vein ➡ coursing behind the aorta ⇨. Retroaortic left renal veins often enter the IVC lower than normal and require lower placement of the VCF.*

Preprocedural Imaging: Variant Anatomy



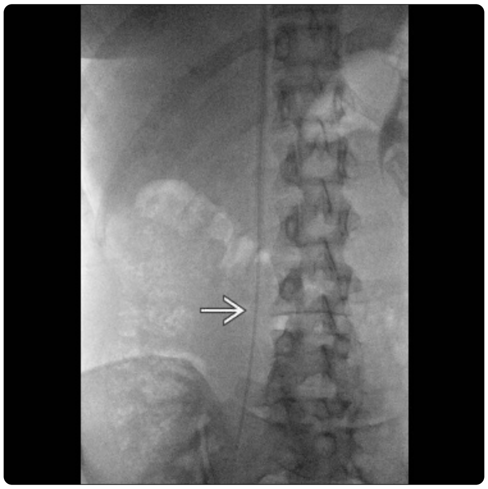
Preprocedural Planning: IJ Thrombosis



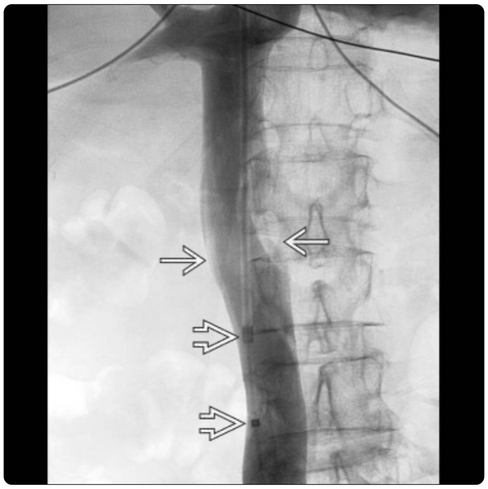
(Left) *Shown in this case is the lower retroaortic moiety of a circumaortic left renal vein ➡ entering the IVC at the L3 level ➦.* **(Right)** *Grayscale US of the right internal jugular (IJ) vein shows heterogeneous hyperechogenicity ⇨ within the vein ➡. There was absent flow on color Doppler imaging compatible with thrombosis. This may be an indication for femoral access for VCF placement.*

(Left) *After venous access is obtained, a wire ➡ is advanced into the IVC. Following this, a sheath or flush catheter will be advanced over the wire and a digitally subtracted cavogram performed.* **(Right)** *Inferior vena cavogram is performed through sheath introducer to evaluate the anatomy, caliber, and patency of the IVC. Note renal vein inflow ➡ at the L1-L2 intervertebral disc space. Also note markers ➡ on the introducer. The distance between them defines the maximum diameter of the IVC for safe placement of filter.*

VCF Placement: Wire Placement

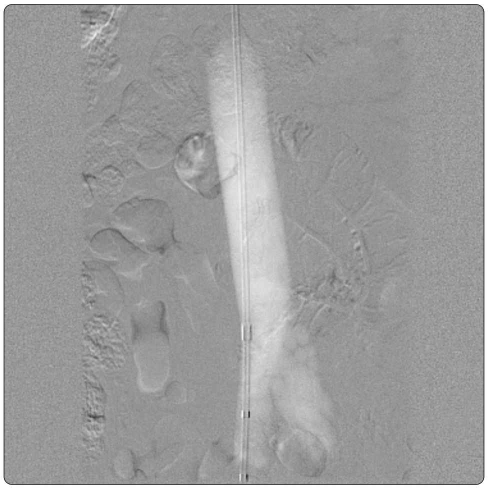


VCF Placement: Initial Cavogram

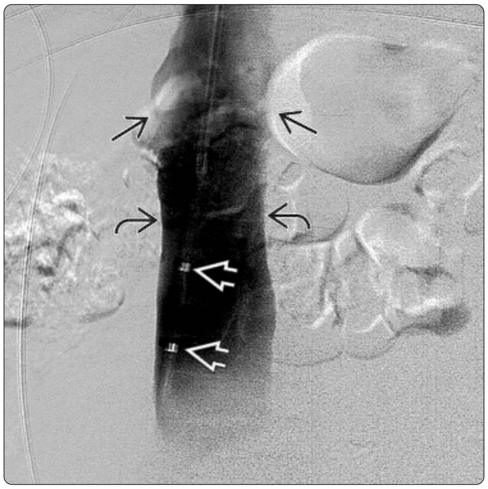


(Left) *CO₂ cavogram can be performed if there is a contraindication to iodinated contrast. It may be more difficult to identify the renal veins as the CO₂ rises anteriorly.* **(Right)** *In this case, the diameter of the vena cava exceeds that of the introducer markers ➡. The distance between markers was 28 mm and the caval diameter ⇨ was 32 mm, consistent with megacava. Bird's Nest filter or bilateral iliac vein filters are indicated. Again note renal vein inflow ⇨.*

VCF Placement: CO₂ Cavogram

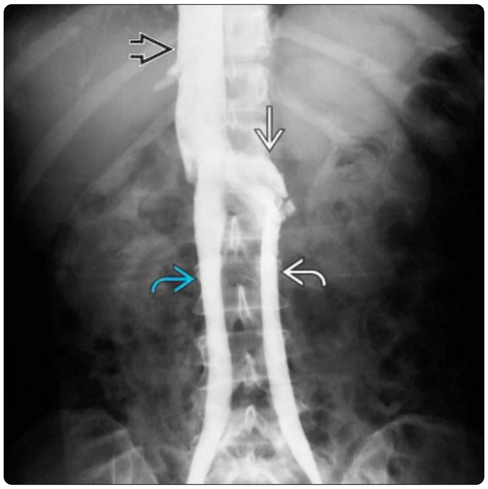


VCF Placement: Megacava

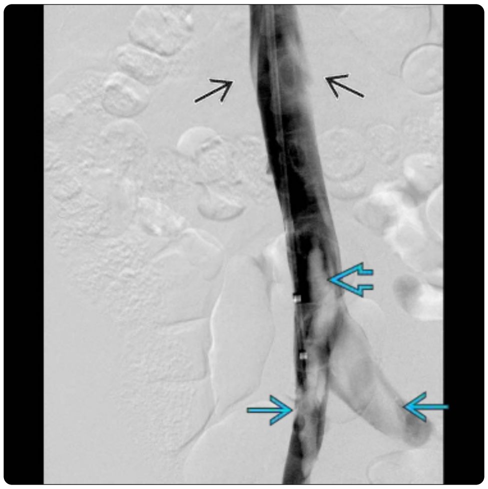


(Left) *This venogram shows infrarenal IVC duplication. The left IVC ➡ drains into a normal left renal vein ➡ and joins the right IVC ⇨ to form a single suprarenal IVC ⇨. Suprarenal or bilateral infrarenal VCF(s) would be needed in this case.* **(Right)** *DSA vena cavography shows filling defects in the common iliac veins ⇨ and infrarenal IVC ⇨, compatible with iliocaval thrombus. Filling defects more superiorly ⇨ represent venous inflow of the renal veins.*

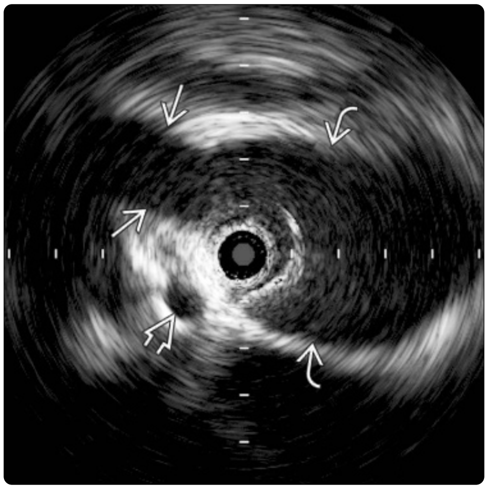
VCF Placement: IVC Duplication



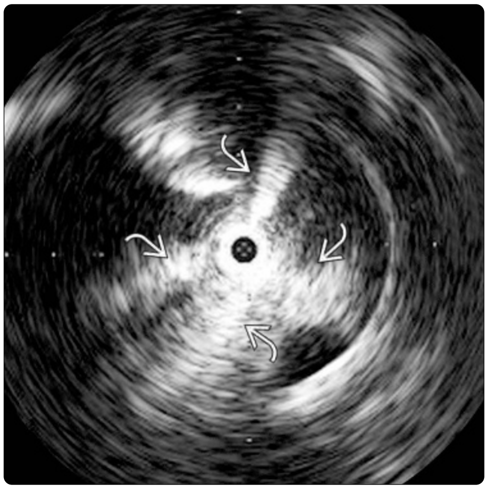
VCF Placement: Iliocaval Thrombus



VCF Placement: IVUS Guidance

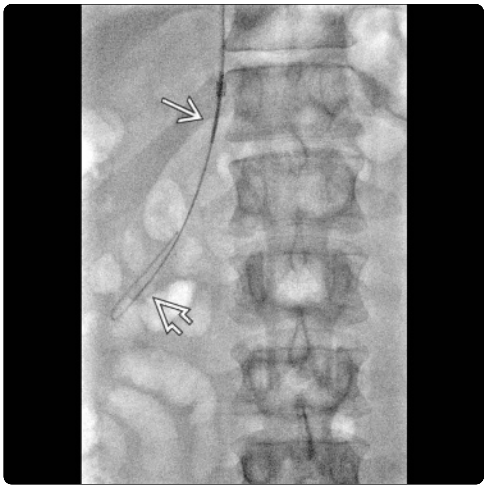


VCF Placement: IVUS Guidance

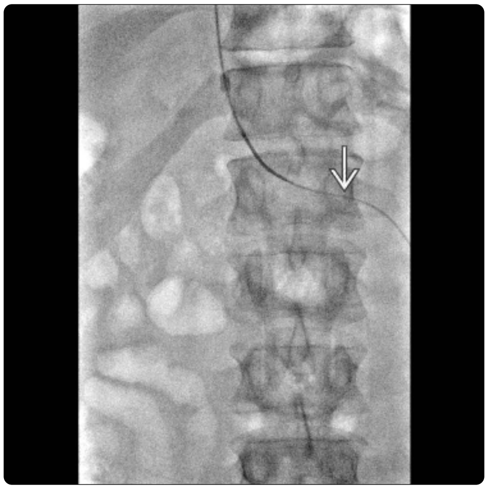


(Left) *Intravascular ultrasound (IVUS) obtained prior to VCF placement shows the IVC ➔ and the right renal vein ➔. The right renal artery ➔ crosses anterior to IVC at renal vein level. IVUS provides a 360° intravascular field of view and may be used when there is a contraindication to intravascular contrast.* **(Right)** *IVUS obtained following IVC filter placement shows multiple linear echogenic structures ➔ radiating from the center of the lumen toward the periphery. These are the struts of the IVC filter.*

VCF Placement: Renal Vein Selection

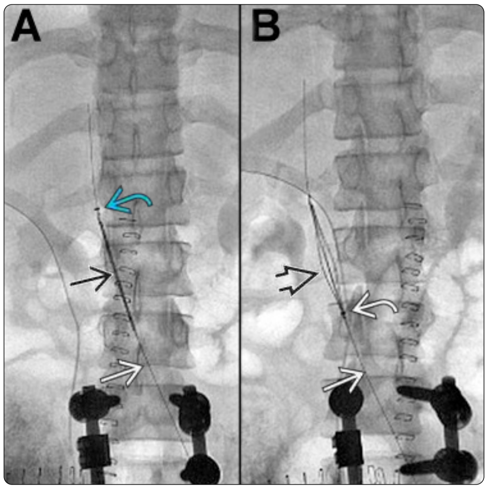


VCF Placement: Renal Vein Selection

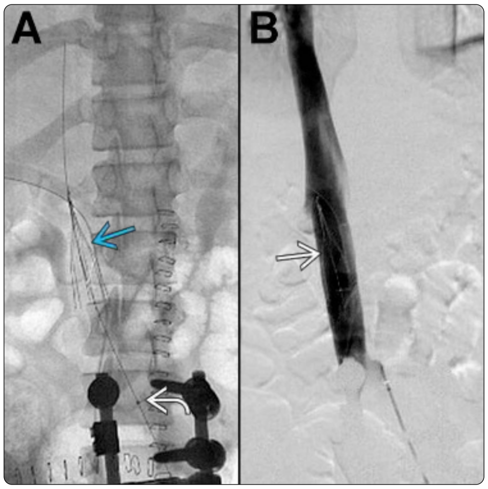


(Left) *If the position of the renal veins cannot be confirmed by venography, each renal vein can be independently selected. Here, the right renal vein is selected using a 45° angled catheter ➔ and a wire ➔.* **(Right)** *The left renal vein ➔ is selected in a similar fashion. Contrast can be injected through the catheter to confirm the location within the vein. It is also helpful to review previous cross-sectional imaging if available to assess the number and location of the renal veins.*

VCF Placement: Femoral Deployment

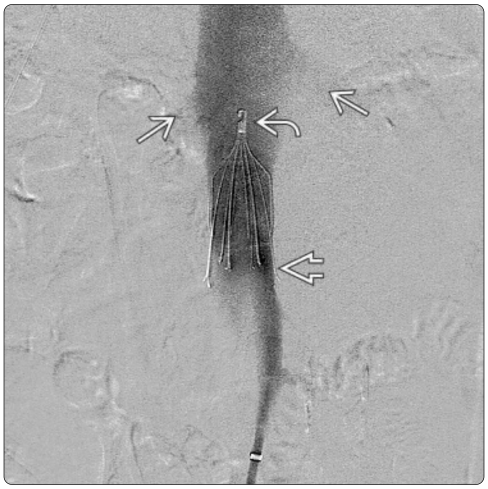


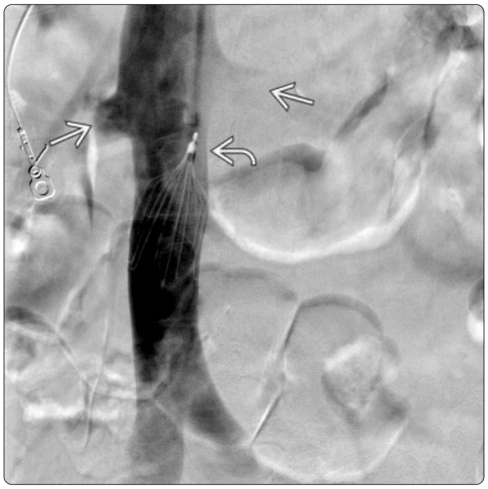
VCF Placement: Femoral Deployment



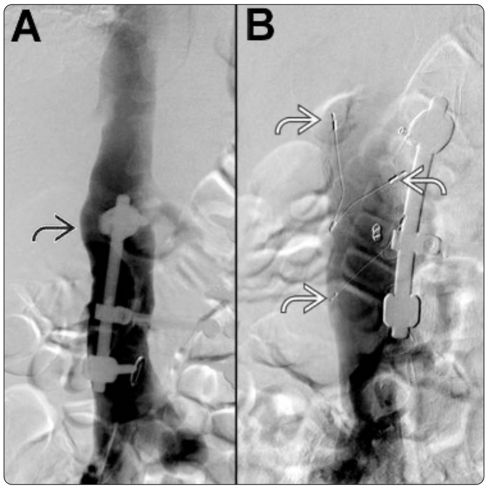
(Left) *(A) The filter ➔ is advanced through the delivery sheath until it is positioned at the sheath tip ➔. The caudal end of the filter abuts a wire ➔ that is used to advance the filter. (B) The wire is held in position while the sheath tip ➔ is withdrawn, thereby unsheathing the filter so that it expands ➔.* **(Right)** *(A) With continued sheath ➔ withdrawal, the filter ➔ fully expands and deploys, and the anchors of the struts engage the IVC wall, thereby securing the filter. (B) A vena cavogram is obtained to confirm the final filter ➔ position.*

(Left) *DSA shows a Bard Denali filter after femoral venous insertion. The filter is centered, without tilt. The filter apex and retrieval hook ↪ are near the inflow level of the renal veins →. Anchors ⇨ at the end of each strut prevent filter migration.* **(Right)** *DSA following VCF placement demonstrates the tip of the filter just below the inflow of the renal veins →, as desired. However, the filter is tilted ↪, which may lead to embedding of the tip in the caval wall. This can make retrieval more challenging.*

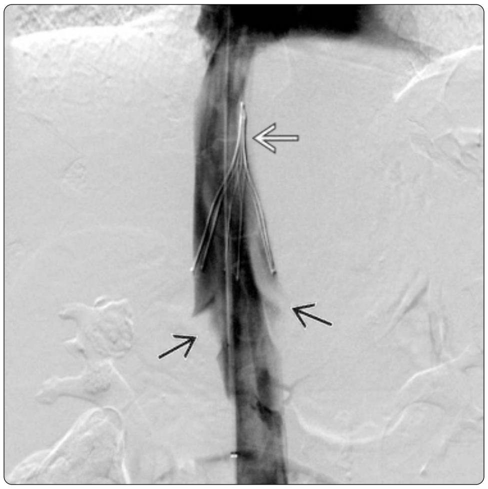

VCF Placement: Optimal Filter Position


VCF Placement: Suboptimal Filter Position

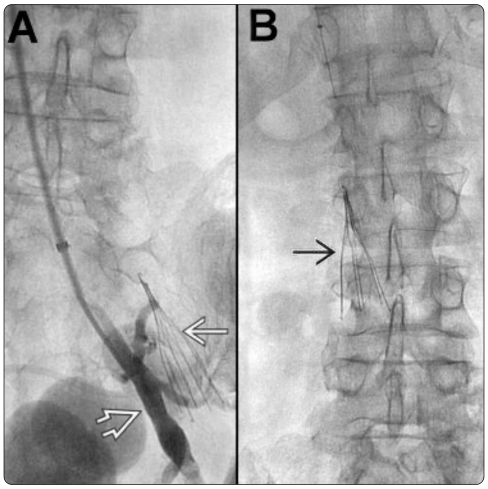
(Left) *(A) DSA cavogram shows a large-caliber IVC ↪ with a diameter of 35 mm, consistent with megacava. (B) A Bird's Nest VCF was placed. It is intended for IVCs with diameters of up to 40 mm. Note that the tangle of wires between the struts ↪ is not well seen radiographically.* **(Right)** *DSA cavogram shows inflow → from both renal veins, indicating their level. A retrievable Option filter → was placed in the suprarenal IVC due to gonadal vein thrombus and the potential for embolization via the left renal vein. Note the filter tilt.*



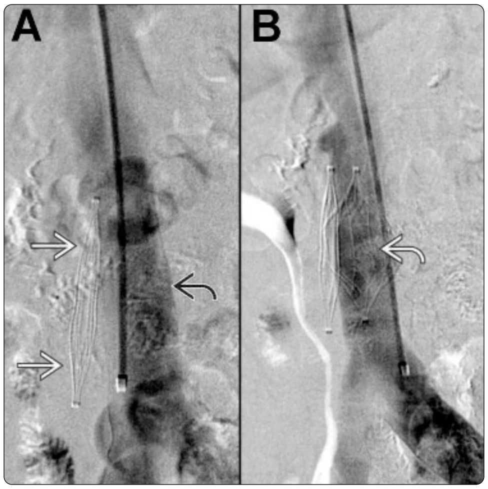
VCF Placement: Megacava


VCF Placement: Suprarenal IVC

(Left) *(A) A temporary VCF → was maldeployed in the left external iliac vein under IVUS guidance. Contrast injection highlights the internal iliac vein ⇨. Familiarity with IVUS is crucial to good outcomes. (B) The VCF → was retrieved and repositioned in the infrarenal IVC.* **(Right)** *(A) A TrapEase permanent VCF → placed via the jugular vein is incompletely opened and outside of the IVC ↪, likely in the right gonadal vein. (B) A 2nd VCF ↪ was placed in the IVC, and the initial filter was left in place.*

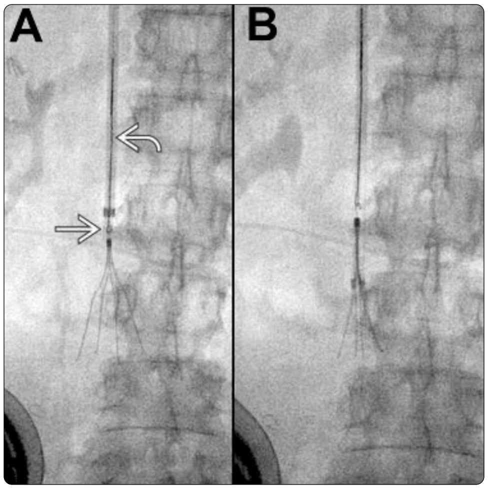


VCF Placement: Incorrect Placement

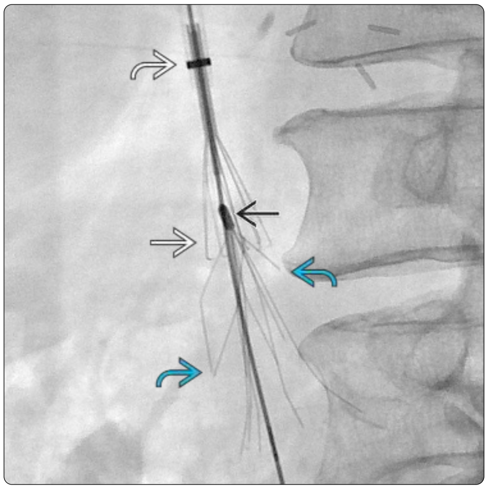


VCF Placement: Incorrect Placement

VCF Retrieval: Standard Technique

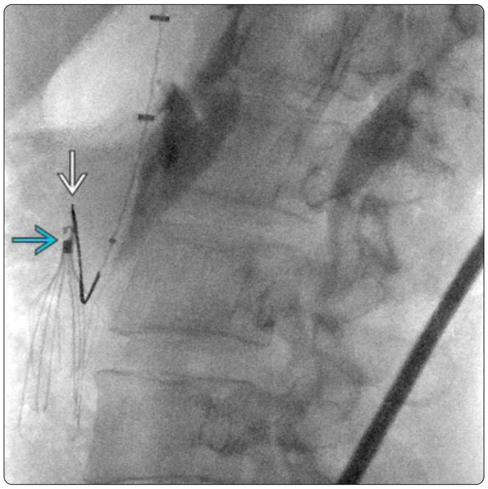


VCF Retrieval: Standard Technique

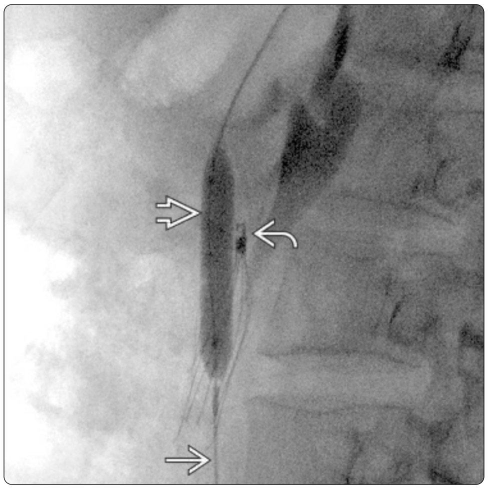


(Left) *(A) In this case, a snare is introduced through a coaxial sheath ➦ and is used to engage the hook ➡ at the filter apex. (B) The sheath is then advanced over the filter to collapse and disengage the legs from the IVC.* **(Right)** *A retrieval cone can be used to remove VCFs ± an apical hook. Once the filter apex → is surrounded by the cone ➡, advancement of the sheath ➦ traps the apex within the cone and collapses and disengages the VCF from the caval wall. Note multiple fractured filter legs ➦ with missing fragments.*

VCF Retrieval: Advanced Techniques

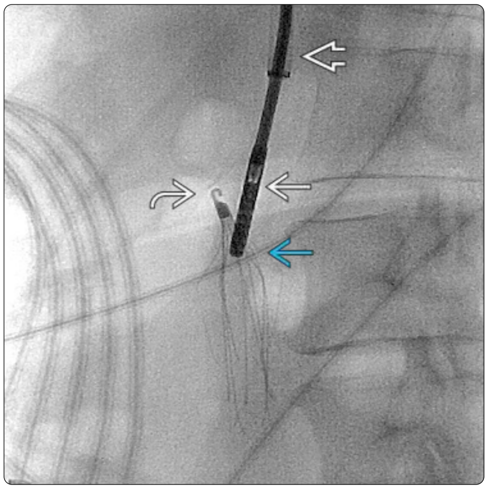


VCF Retrieval: Advanced Techniques

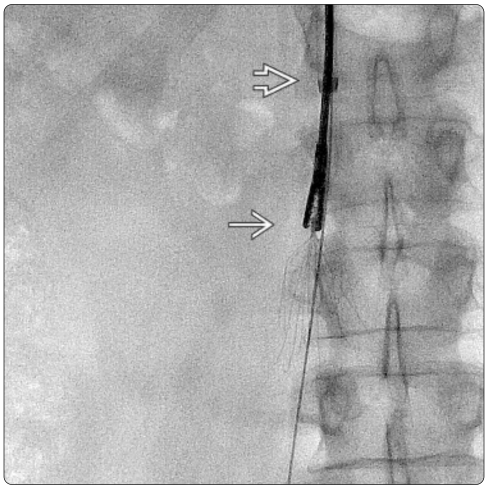


(Left) *An initial cavogram prior to filter retrieval demonstrated anterior tilt of the filter, with the hook embedded in the caval wall. This was confirmed with attempted snare retrieval. The snare ➡ could not be advanced over the apex of the filter → due to ingrowth of the hook.* **(Right)** *A wire ➡ was directed between the VCF and the caval wall anteriorly. An angioplasty balloon ⇨ was then inflated anterior to the VCF, thereby freeing the hook ➦ from the caval wall. The filter was then snared and removed as usual.*

VCF Retrieval: Advanced Techniques



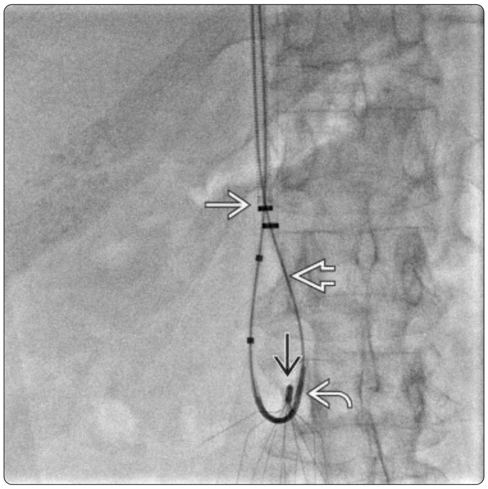
VCF Retrieval: Advanced Techniques



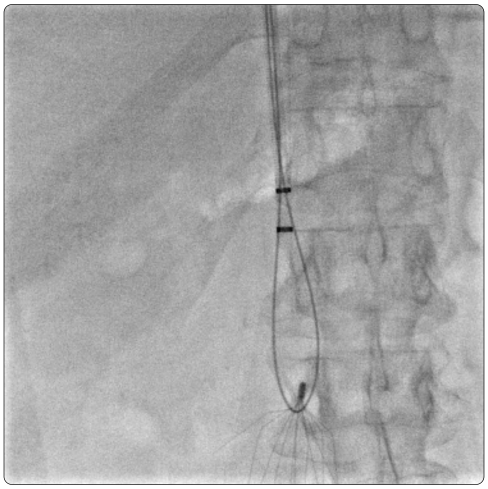
(Left) *In a patient with a VCF hook embedded into the IVC wall, endobronchial forceps ➡ were used to grasp the proximal filter legs →. Traction was applied to free the hook ➦. The hook was then snared and VCF removed through the sheath ⇨.* **(Right)** *An embedded VCF can also be removed with forceps alone if the apex of the filter ➡ can be engaged in a direction parallel to its axis of the sheath. The sheath ⇨ must be large enough (14-16 Fr) to accommodate forceps with the engaged filter.*

(Left) *This case demonstrates removal of a tip-embedded permanent filter. Two sheaths were placed through the jugular vein. Through the 1st sheath* ➡*, a wire* ➡ *and reverse curve catheter* ➡ *were positioned under the filter bulb* ⇨*. The tip of the wire was then snared through the same sheath.* **(Right)** *The tip of the wire was then pulled via the snare through the hub of the sheath and the catheter was removed. Now both ends of the wire are outside the sheath to allow for traction on the apex of the VCF.*

VCF Retrieval: Advanced Techniques

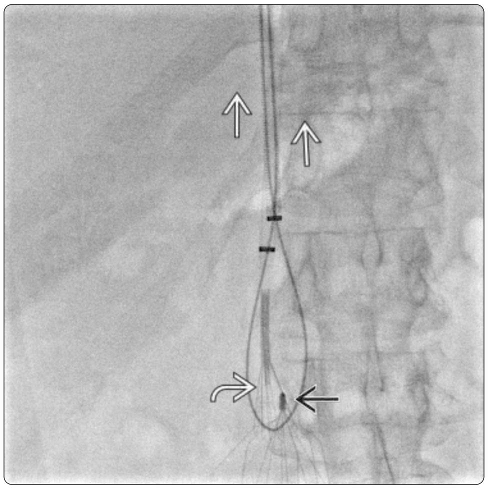


VCF Retrieval: Advanced Techniques

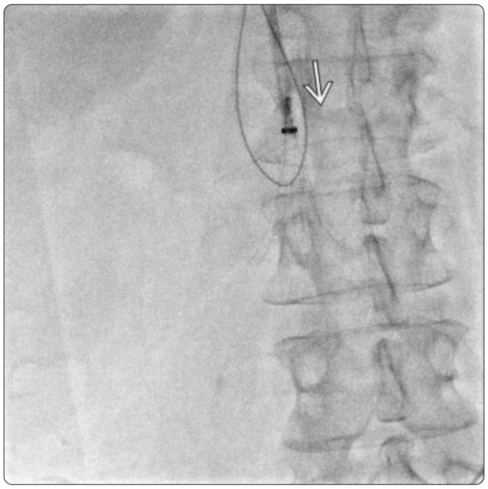


(Left) *With traction* ➡ *applied on the ends of the wire, the bulb of the filter* ⇨ *was pulled away from the caval wall and engaged by a retrieval cone* ➡ *that was inserted through the 2nd sheath.* **(Right)** *After the bulb was engaged by the retrieval cone, the 2nd sheath was then advanced over the cone and the VCF. Note the downward motion* ➡ *of the sheath over the filter. The VCF collapsed and disengaged from the caval wall and was then removed through the sheath.*

VCF Retrieval: Advanced Techniques

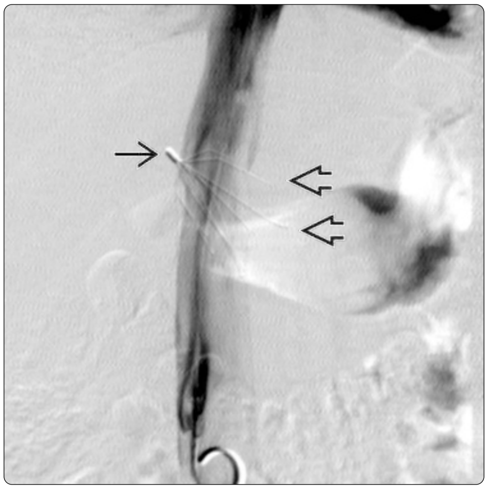


VCF Retrieval: Advanced Techniques

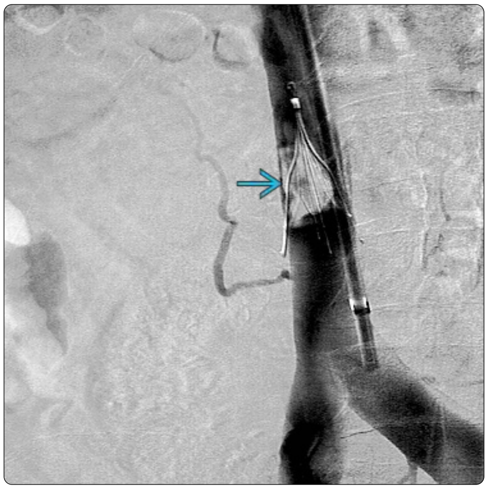


(Left) *DSA cavogram obtained in preparation for retrieval of the malaligned VCF shows the oblique position of the filter and protrusion of both the tip* ⇨ *and legs* ⇨ *beyond the caval wall. Standard retrieval techniques are often ineffective in such cases.* **(Right)** *DSA cavogram performed in preparation for VCF removal demonstrates a small- to moderate-sized filling defect* ⇨ *within the VCF, compatible with thrombus. The filter and thrombus were removed through the sheath without complication.*

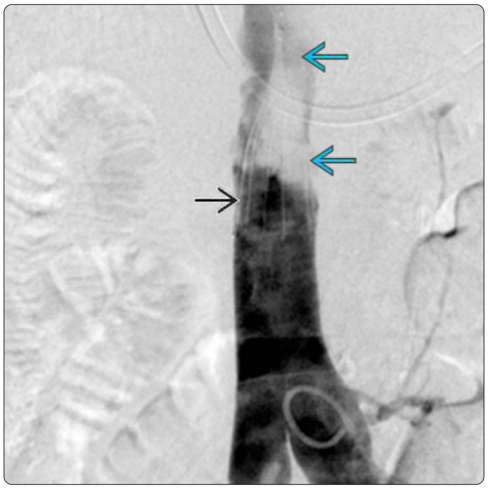
VCF Retrieval: Complications



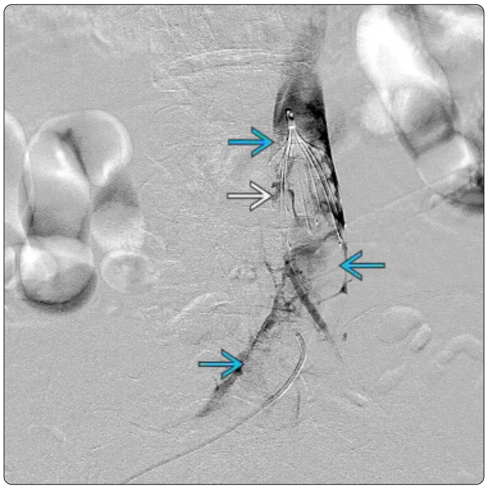
VCF Retrieval: Complications



VCF Retrieval: Complications

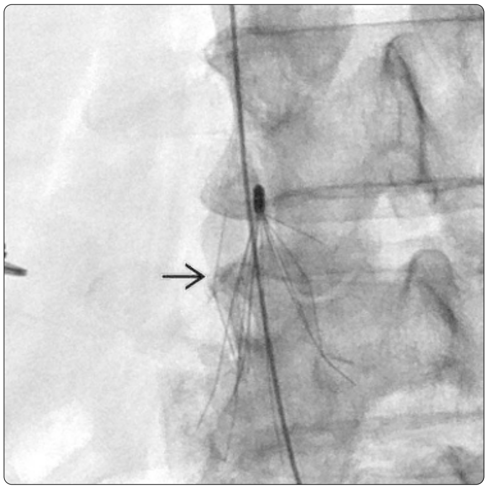


VCF Placement: Complications

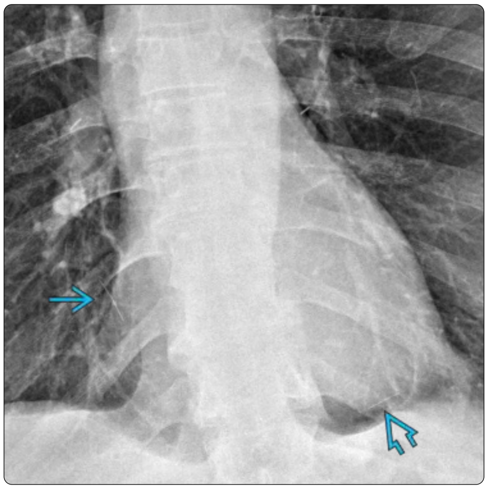


(Left) *A large thrombotic filling defect → within the VCF → extends above the filter margins. Depending on the size of the thrombus, anticoagulation or thrombolysis may be necessary to clear thrombus prior to VCF removal.* **(Right)** *DSA cavogram (prone) in a patient with bilateral lower extremity swelling shows that occlusive filling defects → extend from just above VCF → inferiorly through the left common iliac vein. VCF thrombus can impair flow throughout the IVC, resulting in extensive bilateral DVTs.*

VCF Retrieval: Complications

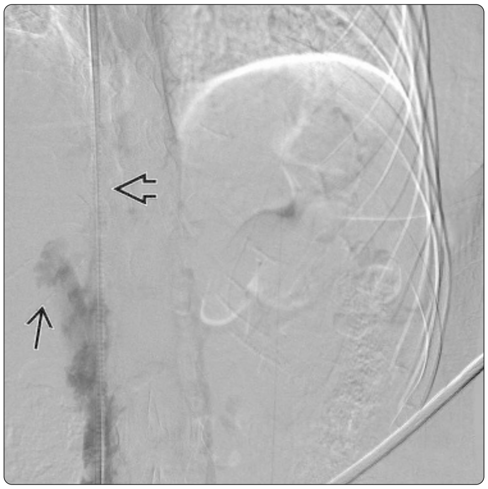


VCF Retrieval: Complications

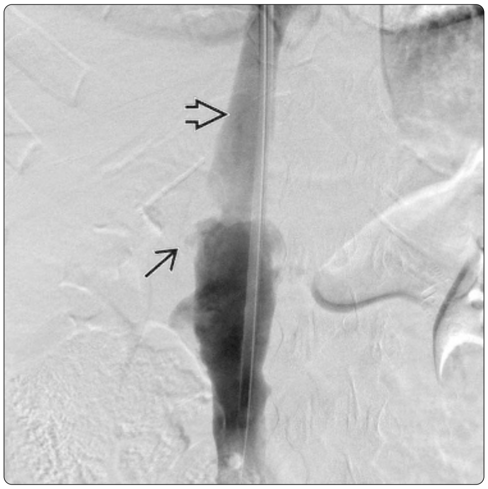


(Left) *Fluoroscopic image was obtained prior to attempted retrieval of a Bard Recovery filter that had been in for several years. There are multiple leg fractures, with 1 leg → dissociated from the bulb but adhered to the caval wall.* **(Right)** *Chest radiograph of the same patient shows linear opacities overlying the lower right medial lung → and base of the heart →. Confirmed by CT, these were VCF fragments located in a small branch of the right pulmonary artery and the right ventricular myocardium, respectively.*

VCF Retrieval: Complications



VCF Retrieval: Complications



(Left) *DSA cavogram following difficult removal of a retrievable filter demonstrates rupture of the vena cava. Note extravasation of contrast → and absent opacification of the suprarenal IVC →.* **(Right)** *The patient immediately became hypotensive. Over the wire, a large-caliber balloon was inflated to restore patency to the IVC and tamponade the extravasation. After prolonged tamponade, antegrade flow was restored → with little remaining extravasation →. Vitals returned to normal and the patient did well.*

Intravascular Foreign Body Retrieval

KEY FACTS

TERMINOLOGY

- **Intravascular foreign body (FB) retrieval**
  - Percutaneous removal of device/object abnormally lodged in artery/vein/cardiac chamber
    - Migrated/maldeployed stents (arterial/venous)
    - Embolization coils, plug occluders
    - Guidewire, sheath, catheter fragments
  - Imaging guidance used during retrieval/removal

PREPROCEDURE

- Indication for FB retrieval
  - FB malpositioned/embolized to undesired location
- Contraindication for FB retrieval
  - Overly excessive removal risk

PROCEDURE

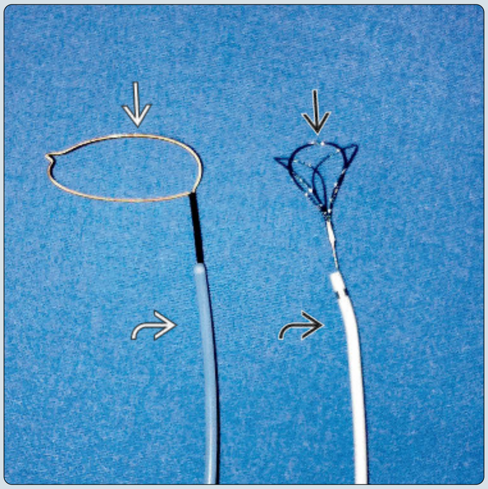
- Choose appropriate access (arterial vs. venous)
- Place appropriate-sized access sheath
  - Based on FB size and retrieval device used
- Place guiding sheath adjacent to FB
- Advance retrieval device out of end of guide catheter
  - Engage/snare FB
- Remove FB through access sheath
- Obtain post retrieval DSA images
  - Evaluate vasculature appearance after FB retrieval

OUTCOMES

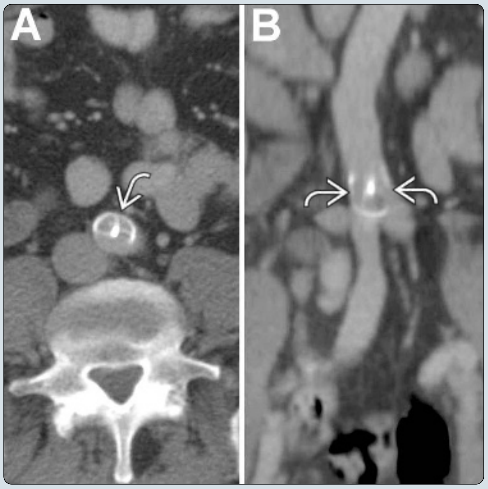
- Most studies report high retrieval success rate (90%)
- Causes for failure to retrieve intravascular FB
  - Inability to engage/snare FB
  - FB embedded/incorporated into vessel
- Potential complications
  - Perforation/laceration of vessel or cardiac chamber
  - Further distal embolization of FB

(Left) *Two snare types used for intravascular foreign body retrieval are shown. The Amplatz GooseNeck snare* ↪ *has a single loop* ➡ *oriented at 90° to the catheter, while the EN snare* ⤷ *has 3 interlaced nitinol loops* ⇨*.* **(Right)** *(A) Axial and (B) coronal images show an intravascular foreign body* ➡ *lodged at the aortic bifurcation. This occluder device, which was placed for a patent foramen ovale, migrated and required forceps use for retrieval.*

Foreign Body Retrieval (Snare Designs)

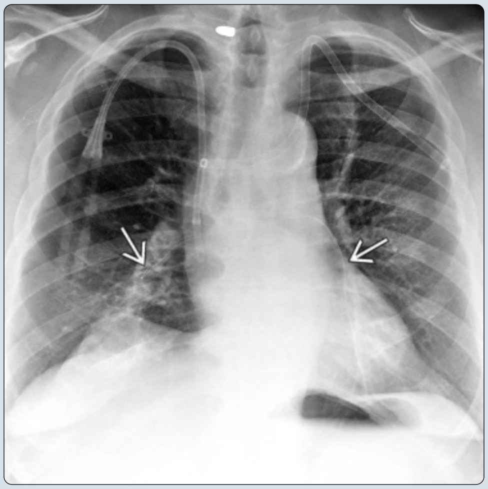


Foreign Body Retrieval (Forceps)

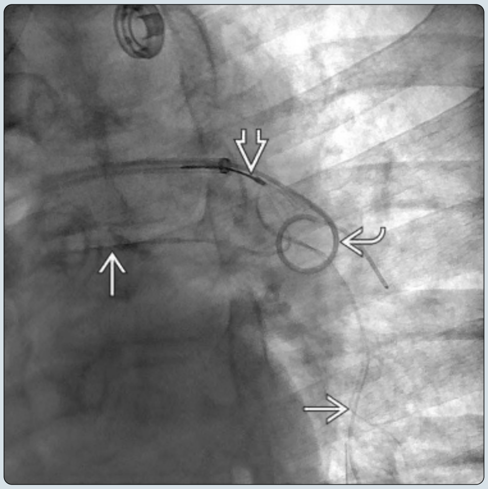


(Left) *Chest radiograph demonstrates a guidewire foreign body* ➡ *straddling the pulmonary trunk bifurcation. The guidewire was lost during hemodialysis catheter placement.* **(Right)** *A sheath was advanced into the pulmonary artery, and a GooseNeck snare* ➡ *and pigtail catheter* ↪ *were advanced through the sheath. The pigtail catheter engaged the wire* ➡ *and pulled it to the center of the vessel lumen where is was grasped by the snare.*

Lost Guidewire (Diagnostic Radiograph)



Lost Guidewire (Snare Retrieval)



Intravascular Foreign Body Retrieval

TERMINOLOGY

Definitions

- **Intravascular foreign body (FB) retrieval**
    - Percutaneous removal of device/object abnormally lodged in artery/vein/cardiac chamber

PREPROCEDURE

Indications

- Removal of FB that is malpositioned or has embolized
- Removal of fractured venous access catheter fragments
- Removal of malpositioned/migrated IVC filter
- Other accessible intravascular FBs
    - Shrapnel, ballistic fragment removal

Contraindications

- Uncorrectable coagulopathy
- Extensive thrombus attached to FB
- Intravascular FB with extreme indwelling time
    - May be endothelialized, incorporated into vessel
    - May no longer pose clinical threat to patient
- FB location with overly excessive removal risk
    - Intracardiac FB perforating myocardium
    - FB causing significant perforation of vessel wall
- Patient with short life expectancy

Preprocedure Imaging

- CT imaging is preferred
    - Best evaluation of FB and adjacent structures

Getting Started

- Things to check
    - Appropriate clinical history/physical examination
    - Details regarding intravascular FB
        - Type and location of FB
        - How long FB has been indwelling
        - Circumstances causing FB
        - Potential complications associated with removal
        - Potential complications if not removed
    - Current medications and allergies
    - Laboratory parameters
        - Creatinine, glomerular filtration rate, CBC, coagulation studies
    - Electrocardiogram
        - Form baseline for intracardiac/pulmonary FB
    - Procedure/sedation/anesthesia consent
- Medications
    - Local anesthesia
    - If indicated, conscious sedation
- Equipment list
    - Materials for gaining vascular access
    - Arterial/venous access sheath
        - May require large caliber or long sheath
            - Depends on retrieval system/tool used
            - Depends on type/size of FB to be retrieved
    - Catheters
        - Flush catheter (e.g., pigtail)
            - May use in combination with tip-deflecting wire
        - Selective catheter (e.g., Cobra, Kumpe, Davis)
            - For catheterization of target vessel
            - Positioning guidewire/snare/sheath adjacent to FB
        - Angioplasty (PTA) balloon catheters
            - May use for repositioning/redeploying stents
    - FB retrieval devices
        - Amplatz GooseNeck snare (Covidien)
            - Single snare loop; diameters from 5-35 mm
            - Placed through 4- to 6-Fr catheter
            - Snare forms 90° angle relative to catheter
            - Microsnare available for microcatheter use
        - Atrieve vascular snare kit (Angiotech)
            - 3 noninterlaced loops; range of diameters
            - Placed through 3.2- to 7-Fr catheter
        - Curry retriever (Cook Medical)
            - Single loop design
        - Dotter retriever (Cook Medical)
            - 30 x 70 mm helical loop basket
            - Good for retrieving round FBs
        - EN snare (Merit Medical)
            - 3 interlaced nitinol loops; range of diameters
            - Mini snare system uses 3.2-Fr catheter
            - Standard snare system uses 6- to 7-Fr catheter
        - Expro Elite Snare/Micro Elite Snare (Vascular Solutions)
            - 0.035" or 0.014" (use with microcatheter)
        - Forceps
            - Various flexible and rigid designs
            - Endobronchial biopsy forceps have "alligator jaws"; may be used to grasp FB
            - Usually requires large-diameter sheath
            - Very effective for engaging/grasping FB
        - Indy OTW Retriever (Cook Medical)
            - 4 loop nitinol wire snare; 40-mm basket

PROCEDURE

Patient Position/Location

- Choice of access depends on FB location and position
    - Arterial vs. venous FB
        - Intraarterial FB usually via femoral approach
        - Intravenous FB usually via jugular or femoral approach
    - Choose access point providing best approach to FB
        - Typically easiest to snare/grasp free end of FB
            - Longitudinally oriented FB usually easier to engage; aligned with vessel course
            - May be necessary to reposition/reorient FB
    - Sometimes beneficial to have 2 access sites
        - One access site to reposition/reorient FB
        - Other access site to engage/retrieve FB
- Type of access sheath depends on several factors
    - Size of FB determines sheath size
        - If large sheath required, influences access choice
    - Location of FB influences length of access sheath
    - Retrieval device used influences sheath size/length
        - Large sheath usually needed for forceps device

Procedure Steps

- **General**
    - Obtain appropriate vascular access
    - Place vascular access sheath
    - Introduce retrieval device through access sheath

  - Engage/capture FB with device
  - Withdraw retrieval device and FB through sheath
  - Obtain DSA images after retrieval
    - Confirm complete removal, evaluate vasculature
      - No fragment(s) remaining, no dissection/perforation/thrombus
- **Using snare catheters**
  - Most commonly used retrieval device
    - 1st choice for catheter/guidewire/coil fragments
  - Choose appropriate snare loop diameter
    - Depends on vessel/cardiac chamber diameter
    - Depends on size/shape of FB
  - Position guide catheter adjacent to free end of FB
  - Advance snare out of end of guide catheter
  - Engage/grasp FB by encircling with snare
    - Can rotate snare using torque control device
      - Allows more precise positioning of loop(s)
    - Usually best to snare cylindrical FB by proximal end
      - Keeps long axis of FB aligned with vessel
  - Advance guide catheter over snare to tighten loop
    - Secures FB in snare loop(s)
  - Withdraw snare and FB through sheath
  - Obtain DSA images after retrieval
- **Using forceps**
  - Useful for retrieving embedded/incorporated FB
    - Very effective for grasping/reorienting FB
    - Can be used to dissect adherent tissue from FB
      - Must be cautious; can tear adjacent vessel wall
  - Many forceps devices very rigid
    - Rigid device requires straight course to target FB
    - Many forceps devices require large access sheath
      - Typically 14- 18-Fr sheath
      - Use long access sheath for forceps; prevents vascular damage from rigid forceps
    - May need to gently curve forceps shaft manually
      - Allows forceps to be directed toward FB; no directability with straight forceps
- **Repositioning/reorienting FB**
  - Retrieval procedure may first require repositioning FB into more favorable position
    - May also be necessary if FB embedded
  - Various repositioning methods
    - Forceps
    - Pigtail catheter with tip-deflecting guidewire
      - Position pigtail catheter adjacent to FB
      - Rotate catheter so pigtail loop engages FB
      - Tighten loop of deflecting wire; secure FB
      - Apply traction to catheter to reposition FB
      - May use reverse curve instead of pigtail catheter
    - Angled catheter and hydrophilic/stiff guidewire
      - Place angled catheter between FB and vessel wall
      - Advance guidewire between FB and vessel wall
      - Advance angled catheter over guidewire
      - Manipulate catheter angle/wire to reorient FB
    - Position angioplasty balloon adjacent to FB and inflate balloon to reorient FB
- **Managing malpositioned stents**
  - Various management techniques
    - Stent retrieval with snare/other retrieval device
    - Creating loop around stent
      - Place guidewire through stent
      - Redirect guidewire retrograde beside stent
      - Guidewire end snared, forms loop around stent
      - Withdraw snare and guidewire simultaneously
      - Pull stent into sheath (usually larger caliber)
    - Repositioning and then redeploying stent
      - Place guidewire through stent
      - Advance PTA balloon over guidewire into stent
      - Partially inflate balloon to capture stent
      - Withdraw PTA catheter with captured stent, or snare PTA catheter/stent from 2nd access
      - Reposition stent/balloon in appropriate vessel
      - Deploy stent by inflating balloon
  - Technique largely depends on stent characteristics
    - Self-expanding nitinol stents difficult to retrieve
      - If expanded in small vessel, difficult to capture
      - Using snare forms waist; difficult to reposition
      - Cannot over-expand stent without fracturing
    - Collapsed balloon-mounted stent
      - Difficult to place guidewire/PTA balloon though stent for capture and repositioning
      - May be more effective to snare/remove stent

Alternative Procedures/Therapies

- Surgical
  - Surgical exploration and removal of FB
- Surveillance monitoring
  - FB inaccessible or stable in asymptomatic patient

POST PROCEDURE

Things to Do

- To prevent possible thrombosis, consider anticoagulation while vessel wall remodels/heals

OUTCOMES

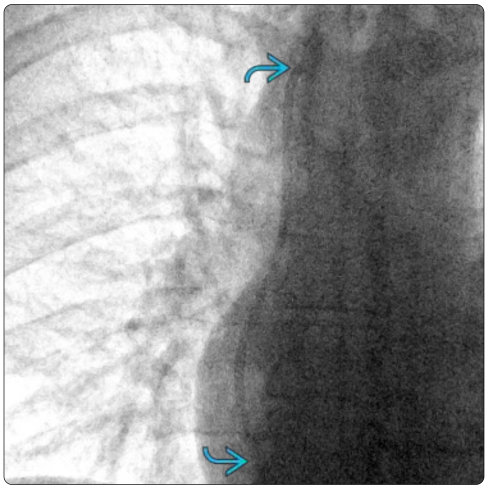
Complications

- Most feared complication(s)
  - Vascular/cardiac injury
    - Perforation/laceration of vessel/cardiac chamber
      - Potential for severe hemorrhage/tamponade
    - Vascular dissection, occlusion, or thrombosis
  - Further distal embolization of FB
    - May lodge in inaccessible location
- Immediate/periprocedural complication(s)
  - Cardiac arrhythmia
    - May be severe if intracardiac FB
  - Access site complications
    - Hematoma, pseudoaneurysm, AV fistula
- **Expected Outcomes**
  - Most studies report high retrieval success rate (90%)
  - Causes for failure to retrieve intravascular FB
    - Inability to engage/snare FB
    - FB embedded/incorporated into vessel

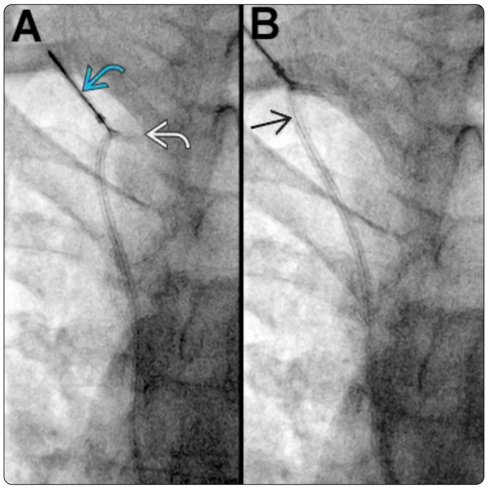
SELECTED REFERENCES

1. Floridi C et al: Intravascular foreign bodies: what the radiologist needs to know. Semin Ultrasound CT MR. 36(1):73-9, 2015

Intravascular Foreign Body (Venous Catheter Fragment)

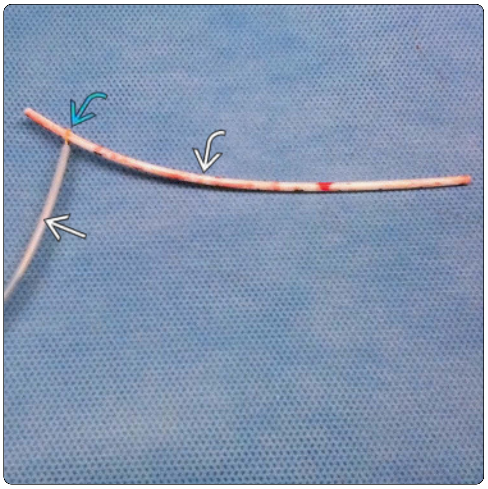


Intravascular Foreign Body (Retrieval With GooseNeck Snare)

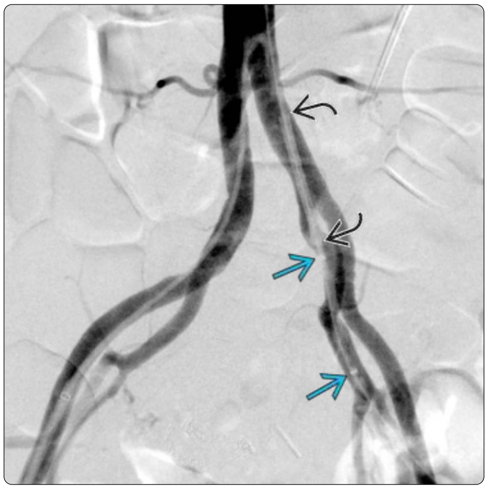


(Left) *Resistance was met while withdrawing the intravascular portion of a port catheter. With further withdrawal attempts, the catheter broke at the point of venous entry. This image shows the catheter fragment* ↪*, which is at risk of embolizing to the heart &/or pulmonary arteries.* **(Right)** *(A) GooseNeck snare* ↪ *was introduced from the right internal jugular vein, and the cephalad end* ↪ *of the fragment was snared. (B) The fragment* → *is removed through a venous access sheath.*

Intravascular Foreign Body (Retrieved Catheter Fragment)

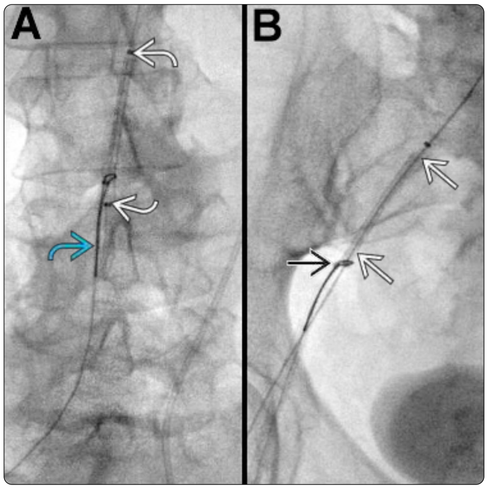


Intravascular Foreign Body (Dislodged Balloon-Mounted Stent)

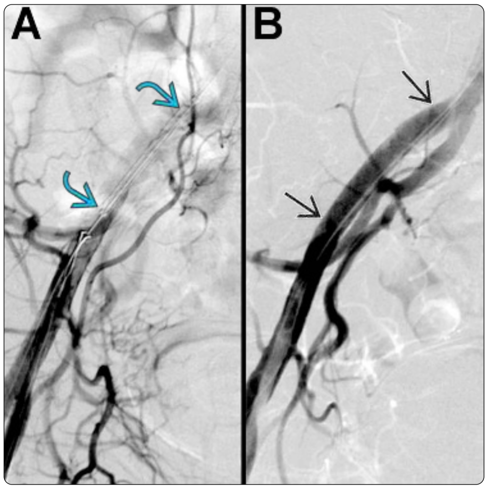


(Left) *After removal, the catheter fragment* ↪ *is still ensnared in the loop* ↪ *of the GooseNeck snare* → *that was used for retrieval. Snares of this type are useful for retrieving foreign bodies that are not incorporated into the vessel wall.* **(Right)** *During attempted placement of a balloon-mounted stent into the left internal iliac artery via brachial access, the stent* ↪ *dislodged from the balloon (denoted by radiopaque markers)* → *and was displaced onto the catheter shaft, proximal to the balloon, as seen on this pelvic DSA.*

Intravascular Foreign Body (Snaring of Balloon and Stent)



Intravascular Foreign Body (Deployment of Stent)



(Left) *(A) The catheter was withdrawn into the distal aorta. A snare* ↪ *was introduced from the right femoral artery and used to ensnare the stent* ↪*. (B) The snare* → *was then used to reposition the stent* → *into its original position on the balloon.* **(Right)** *(A) The snare was used to direct the repositioned stent* ↪ *into the right external iliac artery. (B) The balloon was inflated, and the stent was deployed in the external iliac artery* →*, thus eliminating the potential for the stent to become an intravascular foreign body.*

Pelvic Congestion Syndrome

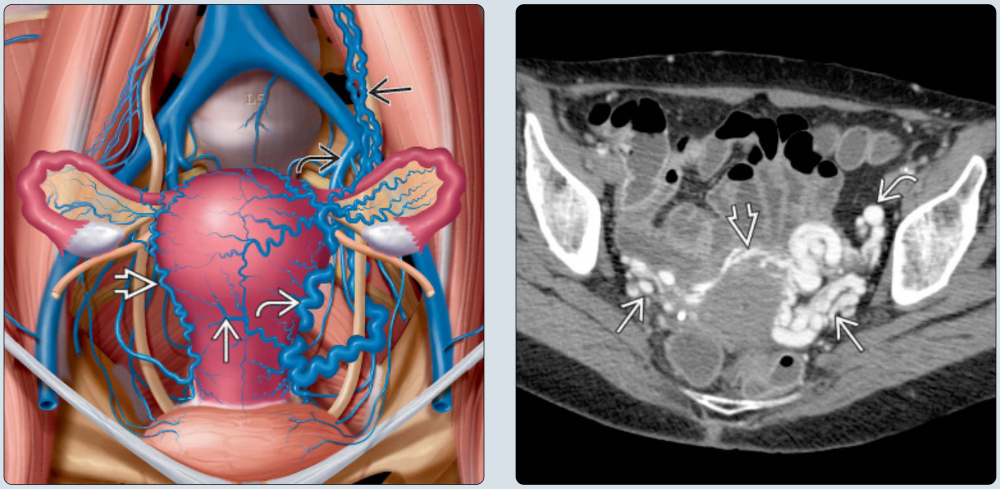
KEY FACTS

TERMINOLOGY

- **Anatomy**
    - Typical ovarian vein (OV) drainage
        - Left OV → left renal vein → IVC
        - Right OV → IVC
    - Utero-ovarian varices → internal iliac veins (IIV) → common iliac → IVC
- **Pelvic congestion syndrome**
    - Chronic condition characterized by pelvic pain, pressure, heaviness
    - Caused by retrograde flow through incompetent valves in dilated ovarian/internal iliac veins
- **Diagnostic criteria**
    - Dilated ovarian, uterine, and utero-ovarian arcade veins (diameter ≥ 4-5 mm)
    - OV contrast reflux/valvular incompetency
    - Contrast cross-filling of pelvic veins, stagnated in pelvic veins

PROCEDURE

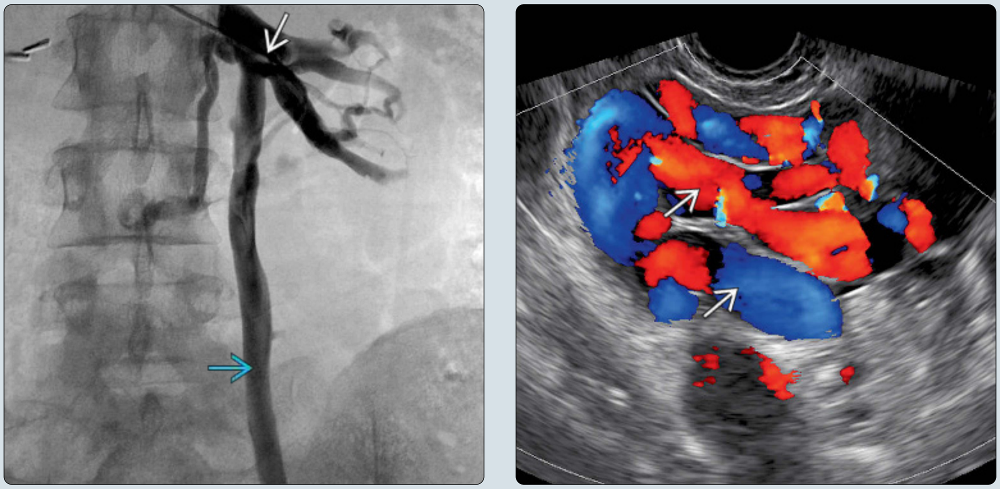
- **Diagnostic venography**
    - Evaluate IVC/left renal/ovarian/common/internal iliac veins
- **Ovarian vein embolization**
    - Calculate volume of pelvic utero-ovarian varices; embolize with sclerosant
    - Deploy coils at distal ovarian vein
    - Alternate 2 mL of sclerosant agent and coils up to OV origin
- **Internal iliac vein embolization**
    - Necessary in 76-100% of patients
    - Sclerosants prefered
- **Postembolization venographic endpoint**
    - Occluded ovarian vein 2-4 mm from origin; internal iliac vein at origin
    - Absence of venous collaterals draining into OV or IIV



Pelvic Varices

Pelvic Varices

(Left) *Coronal graphic shows anatomy typical of pelvic congestion syndrome. Retrograde flow in the left ovarian vein → and internal iliac vein ↪ results in pelvic varices ➥, with transpelvic ➡ filling of the contralateral pelvic veins ⇨.* **(Right)** *CECT in a patient with dysmenorrhea and constant pelvic pain shows tortuous dilated pelvic veins ➡ bilaterally, with cross-filling via the utero-ovarian venous arcade ⇨. The caudal end of a dilated left ovarian vein ➥ is seen.*



Ovarian Vein Reflux

Periuterine Pelvic Varices

(Left) *A left renal venogram ⇨ reveals retrograde reflux of contrast through a dilated left ovarian vein →.* **(Right)** *A transvaginal scan shows numerous dilated tubular structures that are seen to fill with flow on color Doppler ⇨, consistent with dilated periuterine pelvic varices.*

Pelvic Congestion Syndrome

TERMINOLOGY

Definitions

- **Pelvic congestion syndrome (PCS)**: Chronic pelvic pain lasting > 6 months due to pelvic venous incompetence (PVI) and associated venous distension
  - Caused by retrograde flow through incompetent valves in dilated ovarian/internal iliac veins
    - Tortuous, congested pelvic/periuterine veins
  - Risk factors may include heredity, hormonal influence, pelvic surgery, retroverted uterus, history of varicose veins, and multiple pregnancies
  - Symptoms and signs
    - Pressure/heaviness in pelvis/vulva/thighs
      - Often associated with movement, posture, and activities that increase abdominal pressure
    - Vulvar/lower extremity superficial varicosities
    - Dyspareunia (71%), dysmenorrhea (66%)
    - Bladder irritability, urinary frequency,
    - Symptoms worse at day's end, relief when supine, exacerbated by menses
  - Hallmark of PCS is its disappearance after menopause
    - Syndrome may result from gonadal dysfunction, combined with venous dilatation/congestion
- **Anatomic considerations in PCS**
  - Ovarian veins (OV)
    - Left OV drains into left renal vein
      - May communicate with inferior mesenteric vein
    - Right OV drains directly into IVC
      - Enters IVC below right renal vein
    - Often multiple ovarian venous trunks bilaterally
    - Traditionally thought OV incompetency requires vein diameter > 10 mm
      - Diameter does not seem to correlate with PVI
      - Frequent communications between ovarian/internal iliac varices; thus ovarian venous trunks may not be dilated
    - Higher left-side incidence of PCS
      - Absent OV valves on left (15%); on right (6%)
  - Internal iliac veins (IIV)
    - Have both visceral and parietal branches
      - Visceral branches: Vesical, vaginal, and uterine plexi; rectal, labial, clitoral branches
      - Parietal branches: Iliolumbar, superior/inferior gluteal, obturator veins, sacral venous plexus
  - Utero-ovarian arcade
    - Formed by uterine-OV anastomoses
      - Right/left endometrial veins may communicate
    - Incomplete embolization may result in persistent symptoms via utero-ovarian arcade pelvic varices
- **PVI etiology**
  - Multifactorial
    - 1° valvular insufficiency
      - Absent/incompetent valves
    - Venous outflow obstruction
      - "Nutcracker" anatomy compresses left renal vein, elevates venous pressure/may cause reflux
    - Anomalous anatomic variants
      - Retroaortic left renal vein may elevate venous pressure/may cause OV reflux
    - Dysfunctional vasomotor hormonal regulation
      - Uterine/OV hormone sensitive

PREPROCEDURE

Indications

- Chronic (> 6 months duration) noncyclic pelvic pain associated with pelvic varices
- Demonstration of retrograde flow via incompetent gonadal veins into pelvic varices

Contraindications

- Active pelvic inflammatory disease; other infection
  - Should be treated before any embolization
- Other untreated causes of pelvic pain: Endometriosis, adenomyosis, uterine fibroids, pelvic tumors
  - Exclude/treat other causes of pelvic pain
- Uncorrectable coagulopathy
- Severe contrast allergy
  - May prophylactically premedicate
- Severe renal insufficiency

Preprocedure Imaging

- General considerations
  - Asymptomatic patient may have incidental varices
    - Patients with chronic pelvic pain not caused by PCS may also have incidental varices
      - Must clinically correlate imaging findings
  - Imaging often poorly shows ovarian/pelvic varices
    - Supine position reduces hydrostatic pressure
      - Causes venous decompression; false-negative
  - Noninvasive imaging modalities for screening
    - CECT, US, magnetic resonance venography (MRV)
  - Consider venography if high clinical suspicion of ovarian/pelvic varices and equivocal imaging studies
- CECT
  - Dilated OV; enlarged, tortuous pelvic veins
    - OV diameter > 8-10 mm
  - OV reflux
    - Dilated, contrast-filled OV/periuterine veins seen during arterial phase
      - Suggests retrograde flow in OV
  - Variant/abnormal anatomy such as "nutcracker" syndrome/retroaortic left renal vein
    - Renal vein compression results in outflow obstruction; may cause OV reflux
- MR
  - T1WI
    - Pelvic varices have absent signal
      - Due to flow void artifact
    - 3D T1 gradient echo with IV gadolinium most effective sequence for pelvic varices
      - High signal intensity blood flow in pelvic varices on GRE images
  - T2WI
    - Varices usually have low signal intensity
    - May also have hyperintensity/mixed signal due to relatively slow flow
- US
  - Grayscale ultrasound
    - Initial imaging of patient with pelvic pain

  - Color Doppler ultrasound
    - Can identify pelvic varices by using transvaginal US with color Doppler/Doppler spectral analysis
      - Multiple dilated tubular structures around uterus and ovary with venous Doppler signal
      - Tortuous pelvic veins with diameter > 4 mm; slow blood flow (about 3 cm/sec)
      - Transpelvic collateral venous communication between bilateral pelvic varicose veins
- Venography
  - Directly shows tortuous dilated ovarian/pelvic veins
    - Gold standard diagnostic imaging modality
  - Selective OV catheterization with contrast injection demonstrates
    - Reflux of contrast from left renal vein into OV, often with venous dilatation
    - Uterine venous engorgement
    - Congestion of ovarian venous plexus
    - Filling of ipsilateral/contralateral pelvic veins
    - Vulvovaginal or thigh varicosities
  - Diagnostic criteria
    - Ectatic ovarian, uterine, and utero-ovarian arcade veins (diameter ≥ 5 mm)
    - OV contrast reflux/valvular incompetency
    - Cross-filling of pelvic veins
    - Vulvovaginal or thigh varicosities
    - Contrast medium stagnation in pelvic veins

Getting Started

- Things to check
  - Clinical history and physical evaluation
    - Evaluation of symptoms; exclude other diagnoses
    - Comprehensive gynecological evaluation and pelvic examination
  - Allergies
    - Review patient's allergies and treat appropriately
    - Treatment of PCS is never emergent
      - Severe allergies may require ≥ 12 hour treatment with oral steroids
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Normal creatinine and GFR > 60
    - Complete blood count (CBC)
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ration (INR) ≤ 1.5
      - Normal prothrombin time (PT), partial thromboplastin time (PTT)
  - Consent
    - At a minimum, discuss potential post-embolic pain, non-target embolization, injury to non-target veins, contrast-induced nephropathy, infection, access-site pain, incomplete resolution of symptoms
  - Review cross-sectional imaging
    - Evaluate OV for dilation/contrast filling
    - Exclude left renal vein for compression/variant anatomy
    - Look for enlarged pelvic varices
    - Insure patency of planned venous approach (IVC/SVC)
      - Exclude IVC filters or other hardware which could interfere with procedure
  - Overnight admission for observation
    - Antiemetics and analgesics may be necessary
  - Special considerations
    - Society for Vascular Surgery, American Venous Forum recommends ovarian and pelvic vein embolization for PCS (grade 2B recommendation)
- Medications
  - 1-2% lidocaine (local anesthesia)
  - Antibiotic prophylaxis: Levaquin 500 mg IV, 1 dose
- Equipment list
  - Catheters
    - Left renal vein
      - 7-Fr guide/Cobra catheter (femoral access)
      - Cobra/H-1/multipurpose angled (MPA) catheter (jugular/brachial access)
    - Left OV
      - 4- to 5-Fr JB-1/hockey stick/MPA/Cobra catheter via renal vein guiding catheter (femoral access)
      - Cobra/MPA/H-1 catheter (jugular/brachial access)
    - Right OV
      - 7-Fr reverse-curve guide catheter/5-Fr Simmons-2 for catheterization of orifice (femoral access)
      - 4- to 5-Fr JB-1/hockey stick-shaped catheter for distal catheterization (femoral access)
      - Cobra/MPA/H-1 (jugular/brachial access)
    - Internal iliac veins
      - Cobra catheter for contralateral access; form Cobra into Waltman loop or use 5-Fr Roberts/Simmons catheter for ipsilateral (femoral access)
      - Davis/MPA/H-1 (jugular/brachial access)
  - Balloon-occlusion catheters for IIV/OV embolotherapy
    - 7-Fr Berman wedge catheter
  - Embolic materials: Solid/liquid/temporary agents
    - Permanent solid agents
      - 0.035" coils; upsize 3-5 mm > vein diameter
      - Amplatzer occlusion plugs
    - Liquid sclerosant agents
      - 3% sodium tetradecyl sulfate (STS)
      - Sodium morrhuate (5%)
    - Gelfoam slurry (temporary agent)
    - Contrast agents mixed with sclerosants
      - Lipiodol (Ethiodol, Savage Laboratories, Melville, New York)

PROCEDURE

Patient Position/Location

- May access OVs from either transjugular or transfemoral venous approach
- May access internal iliac veins from either transjugular or transfemoral venous approach

Equipment Preparation

- Embolic material preparation
  - Sclerosant agents
    - 3% STS proposed preparations
      - Mix 3:2:1 ratio of air:Lipiodol:STS (radiodense)
      - Mix 4:1 ratio of air:STS (radiolucent)
      - Combine with Gelfoam slurry

    - Sodium morrhuate (5%)
      - Combine with Gelfoam slurry

Procedure Steps

- **Procedure-specific goals**
  - Evaluate bilateral ovarian and IIV for evidence of PCS, determine extent of venous involvement
  - Completely embolize involved OVs, consider embolization of enlarged internal iliac varices
- Obtain venous access
  - May use either jugular or femoral venous access
    - Access choice depends on operator preference
  - Place 7-Fr venous access sheath
    - Facilitates exchange of various catheters
  - Can also use arm vein access
    - 5-Fr vascular sheath
- **Venography (initial)**: Assess IVC, left renal/gonadal/common/IIV; confirm pelvic venous incompetency
  - Introduce 7-Fr guiding catheter into left renal vein
    - Perform left renal venogram
      - Confirm normal left renal anatomy; no anatomic variant/"nutcracker" syndrome
      - May use Valsalva maneuver/Trendelenburg position to elicit OV reflux
  - Important to determine anatomic variations/duplication, venous drainage patterns/collaterals
- **Ovarian venography**: Introduce 4- to 5-Fr selective catheter via guide catheter
  - Selectively catheterize left OV
    - Perform proximal left ovarian venogram
    - Valsalva maneuver to accentuate reflux/varices
  - Selectively catheterize right OV
    - Perform proximal right ovarian venogram
    - Valsalva maneuver to accentuate reflux/varices
  - If venogram confirms valvular incompetence
    - Advance selective catheter caudally in distal OV to pelvic level; perform venography
    - Use hand injection venography to determine contrast volume required to fill pelvic utero-ovarian varices; used to calculate appropriate sclerosant volume
- **Internal iliac venography**: Introduce occlusion balloon catheter into IIV origin
  - If using transfemoral approach
    - Contralateral IIV
      - Advance Cobra catheter into contralateral common iliac vein
      - Selectively catheterize IIV
      - Advance guidewire into main trunk
      - Exchange Cobra for occlusion balloon catheter
      - Perform occlusion balloon catheter venography
      - Determine contrast volume needed to opacify varices; use to calculate sclerosant volume
      - Determine venous drainage pattern
    - Ipsilateral IIV
      - Form Cobra catheter into Waltman loop; alternatively use Roberts/Simmons catheter
      - Selectively catheterize IIV
      - Repeat same steps as for contralateral vein
  - If using transjugular approach
    - Selectively catheterize either IIV using Davis/MPA/H-1 catheter
    - Repeat same steps as for transfemoral approach
- **Embolization**
  - Important to embolize entire length of incompetent vessel, including tributaries
  - Following OV embolization, incompetent iliac veins may sustain pelvic varicosities
    - IIV evaluation and treatment is generally recommended
  - **OVs**
    - **Embolic agent: Sclerosant**
      - Typically utilize STS foam
      - Mix 3 ml air: 2 mL of 3% STS: 1 ml saline (radiolucent) or ethiodol (radiodense)
      - Place occlusion balloon catheter at OV origin
      - Inflate balloon; inject contrast to determine volume of sclerosant agent required to completely fill pelvic utero-ovarian varices
      - Inject calculated volume of sclerosant agent, observe displacement of static contrast during injection
      - Keep balloon inflated for 5 minutes
      - Caution: Sclerosants can inadvertently disperse systemically, especially in high-flow situations
    - **Embolic agent: Coils**
      - Advance 4- to 5-Fr straight catheter to pelvic brim
      - Deploy coils along entire OV length to origin
      - Venous duplications/multiple trunks may require individual embolization
      - Expensive option depending on coil type used
    - **Embolic agent: Combination coils/sclerosant (preferred method)**
      - Advance 4- to 5-Fr straight catheter to pelvic brim, deliver coil (typically 6-8 mm), then advance catheter inferior/beyond coil if possible
      - Inject contrast during Valsalva, calculate contrast volume filling pelvic varices, deliver calculated volume of sclerosant (STS foam)
      - Retract catheter into coil mass, deploy additional coils to allow tighter packing
      - Retract catheter (5-10 cm), deploy coil, advance catheter inferior/beyond coil
      - Inject contrast/calculate volume required to fill vein between coils, inject sclerosant (STS foam)
      - Retract catheter into coil mass, deploy additional coils to allow tighter packing
      - Repeat: alternate sclerosant agent and coils along OV course, up to origin
  - **IIV/varices**
    - Position inflated balloon occlusion catheter tip at origin of IIV: Occlude venous outflow
    - Inject sclerosant material to equal maximum volume of contrast used for venography
      - Sclerosant preferred over coils; penetrates varices/less risk of nontarget embolization
    - Keep balloon inflated for 5 minutes
    - Deflate balloon; aspirate excess sclerosant
    - Repeat in contralateral IIV
- **Postembolization venographic endpoint**
  - OV occlusion 2-4 mm from origin

  - Occlusion of IIV at origin
  - Absence of venous collaterals draining ovarian or IIVs

Alternative Procedures/Therapies

- Surgical
  - Laparoscopic transperitoneal OV ligation
    - Complete pain remission and absence of pelvic varicosities for 12 months in one study
  - Hysterectomy, bilateral salpingo-oophorectomy with venous ligation
    - Longer hospitalization and postop recovery time
    - Fertility issues in reproductive-aged patients
  - Hysterectomy alone considered obsolete treatment for PCS
- Other
  - Medical management
    - If underlying disorder (e.g., hormonal imbalance)
      - ☐ Possible treatment with medroxyprogesterone 50 mg/day or goserelin (GnRH analog) 3.6 mg/month x 6 months
      - ☐ Estrogen is venous dilator; low estrogen states/antagonizing estrogen with progesterone may result in improvement
- Laparoscopic and endovascular management have comparable outcomes

POST PROCEDURE

Things to Do

- Overnight admission for observation/pain control
  - Ensure adequate postprocedural analgesia
    - Patient-controlled analgesia pump with hydromorphone or fentanyl
- Nonsteroidal antiinflammatories
- Clinical follow-up at 3, 6, and 12 months

Things to Avoid

- Avoid heavy lifting & Valsalva maneuvers

OUTCOMES

Complications

- Most feared complication(s)
  - Nontarget coil embolization to pulmonary arteries
    - Reported with IIV embolization
- Immediate/periprocedural complication(s)
  - OV perforation
    - When recognized, advance catheter beyond perforation into undamaged vein segment
      - ☐ Coil embolization of entire OV occludes injured segment
  - Postembolization syndrome: 80-90% of patients
- Delayed complication(s)
  - Infection
- Other complications
  - Hematoma/bleeding at access site
  - Deep vein thrombosis/pulmonary embolus
  - Allergic reaction to iodinated contrast material
  - Contrast-induced nephropathy
- Overall complications reported in 3-9% of cases following embolization

Expected Outcomes

- Complete or partial symptom improvement in 68-100% of patients with PCS treated with embolization
  - Long-term clinical improvement studies
    - 93% improved at 60 months
    - 83% improved at 45 months
    - 64% total relief, 29% partial relief at 14 months
- Pelvic pain visual analogue scale studies
  - 7.3 initial dropped to 0.8 post embolization
  - 7.8 initial dropped to 3.2 in embolization group vs. drop to 4.6 in bilateral oophorectomy group (5.6 unilateral)
- 6-32% of patients with PCS do not have substantial relief following pelvic venous embolization
- No significant change in ovarian hormonal levels pre- and post embolization
- No negative impact on menstrual cycle or fertility
- Reports of successful pregnancies post embolotherapy
- No randomized controlled studies comparing embolization agent
- OV embolization: 100% technical success
  - Left: 33% recurrence
  - Right: Typically embolized in conjunction with left
- 76-100% of patients require IIV embolization for PCS control
  - May be performed concurrently with OV embolization or staged 4-6 weeks later
  - Bilateral: 100% technical success with sclerosants

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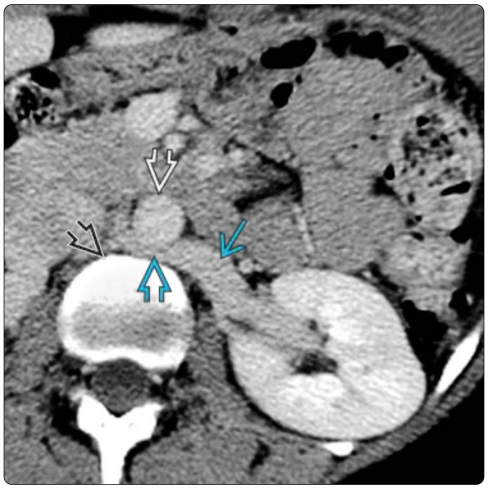
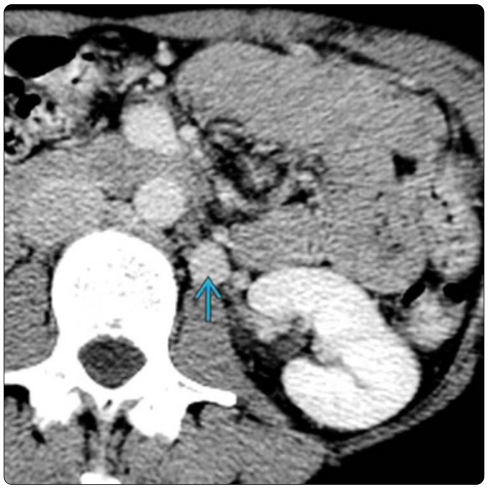
Venous Phase (Left Renal Vein Compression)

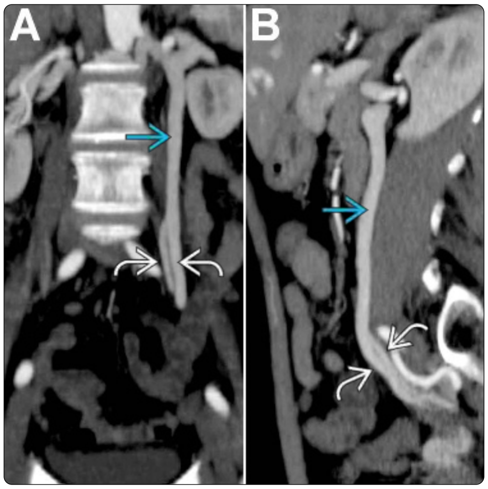


Venous Phase CECT (Enlarged Left Ovarian Vein)

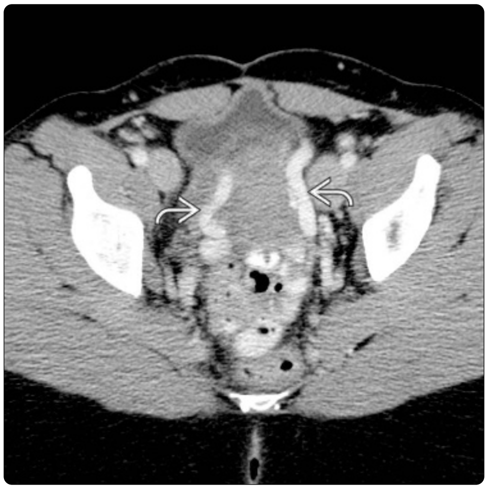


(Left) *Axial venous phase of a CECT shows a distended retroaortic left renal vein* → *in a patient with a history of chronic left-sided pelvic discomfort. Compression of the retroaortic portion* → *of the left renal vein between the vertebra* ⇨ *and the aorta* ⇨ *may result in elevated venous hydrostatic pressure and ovarian vein reflux.* **(Right)** *Reflux from the dilated left ovarian vein* → *may result in pelvic venous engorgement or varices and the resultant symptoms of pelvic congestion syndrome.*

Venous Phase CECT (Enlarged Left Ovarian Vein)

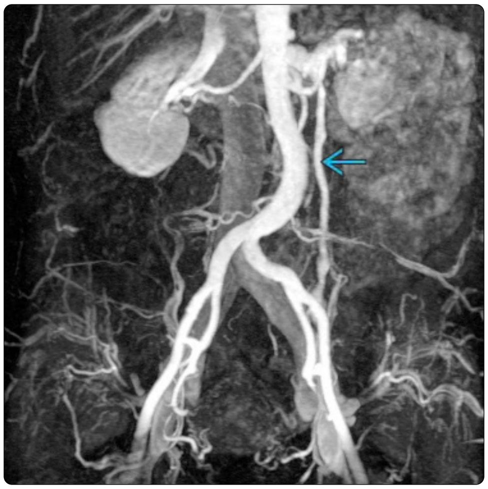


Axial (Pelvic Varicies)

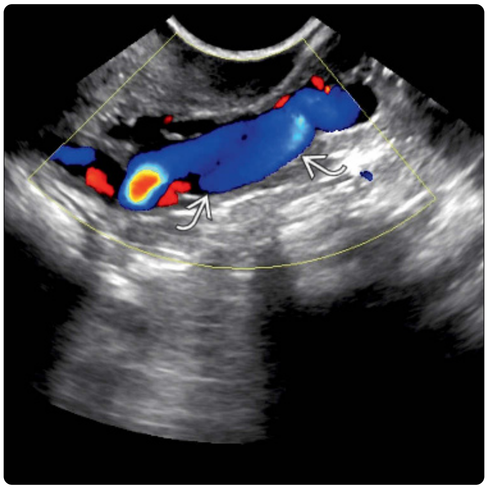


(Left) *(A) Coronal and (B) sagittal CECT reformations show a markedly dilated left ovarian vein* → *opacified along its entire length during the arterial imaging phase, suggesting venous reflux. The more caudal aspect of the vein is duplicated* ↪*. Multiple ovarian vein trunks are a frequent finding in this entity, and duplications may require individual embolization.* **(Right)** *Axial CECT of the pelvis shows contrast-filling of bilateral, dilated and tortuous paruterine pelvic veins* ↪ *that are typical of pelvic congestion syndrome.*

Coronal MR (Enlarged Left Ovarian Vein)

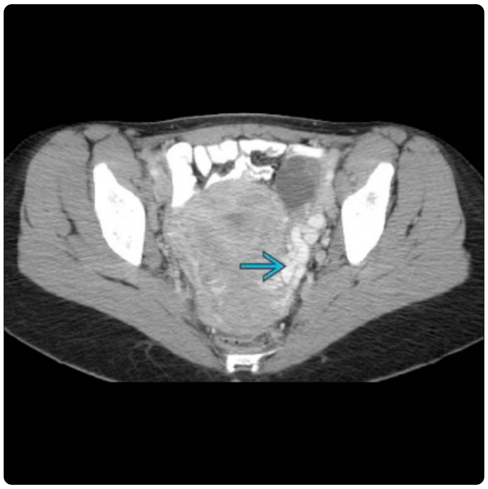


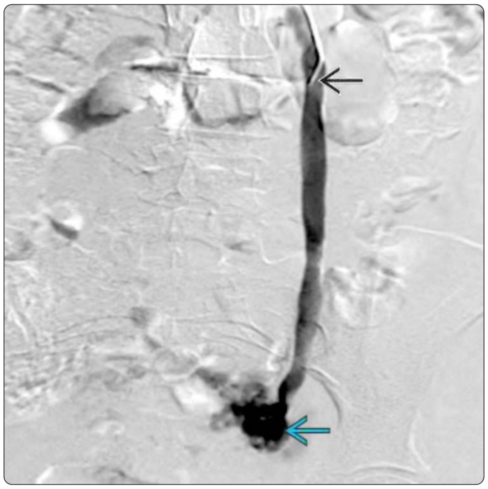
Color Doppler Transvaginal Ultrasound (Enlarged Periuterine Veins)



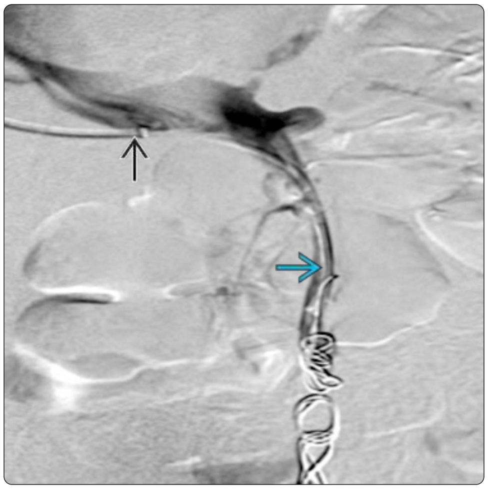
(Left) *Coronal MIP from a gadolinium-enhanced MRA examination shows opacification of an enlarged left gonadal vein* → *during the arterial phase of image acquisition, consistent with ovarian vein reflux. 3D T1 gradient echo imaging with IV gadolinium is the most effective MR sequence for showing pelvic varices.* **(Right)** *A markedly dilated adjacent vein* ↪ *in the left adnexa corresponds to the CECT imaging findings. Pelvic veins > 4 mm in diameter are considered abnormal.*

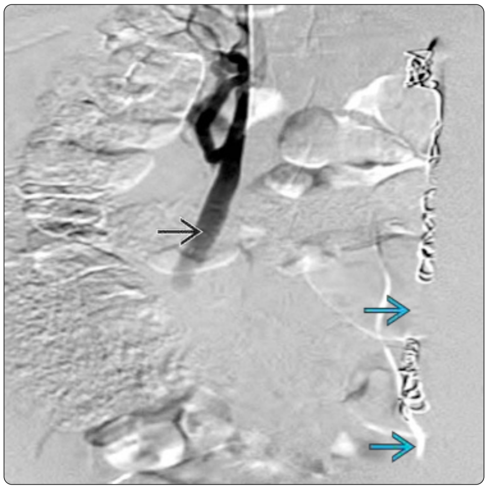
(Left) *A pelvic CECT reveals enlarged periuterine veins* → *in a patient with chronic pelvic pain and heaviness. Symptoms report worsened after prolonged standing or at the day's end.* **(Right)** *A 5-French catheter was advanced into the left ovarian vein* →*. Contrast injected during Valsalva confirms venous reflux through the ovarian vein and into periuterine veins* →*.*


Axial CECT (Enlarged Periuterine Varices)

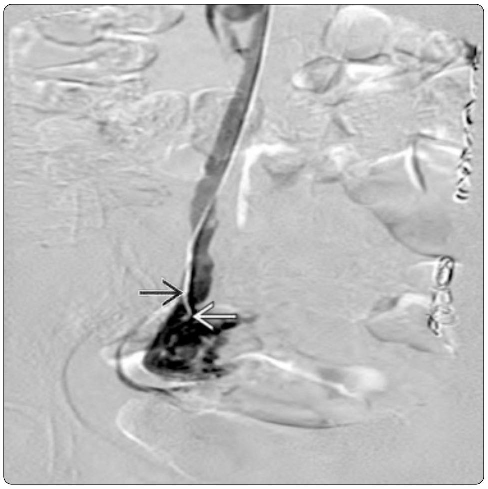

Diagnostic Venogram

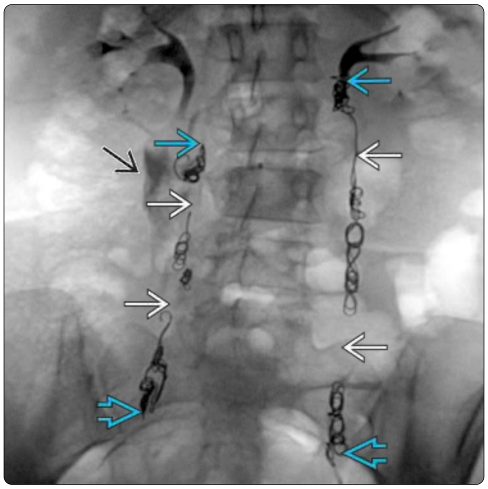
(Left) *With a 5-French catheter* → *positioned in the left renal vein, a microcatheter* → *was advanced into the left ovarian vein, and coils were deployed from the pelvic brim to the superior extent of the gonadal vein.* **(Right)** *A right ovarian venogram* → *was then performed. Notice intermittent uncoiled segments of the mid-left ovarian vein* →*. "Sandwiching" inexpensive sclerosants or Gelfoam between coils can significantly decrease the expense of the procedure.*


Left Ovarian Vein Embolization

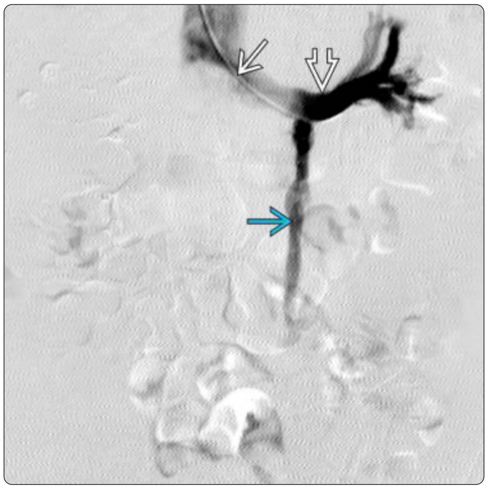

Right Ovarian Vein Embolization

(Left) *A 5-French catheter* → *and microcatheter* ➡ *were advanced through the right ovarian vein to the pelvic brim to begin embolization.* **(Right)** *Bilateral ovarian vein embolization was achieved with coils deployed from pelvic brim* ⇨ *to superior extent of ovarian veins* →*. Embolize with coils deployed continuously along the vessel length, or with alternating coils and sclerosant* ➡ *throughout the treatment zone. Note contrast extravasation outside of the right ovarian vein* →*.*

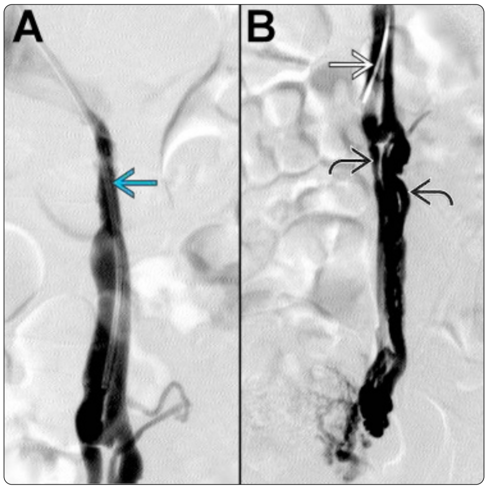

Right Ovarian Vein Embolization


Post Embolization

Transjugular Embolization (Initial Left Renal Venography)

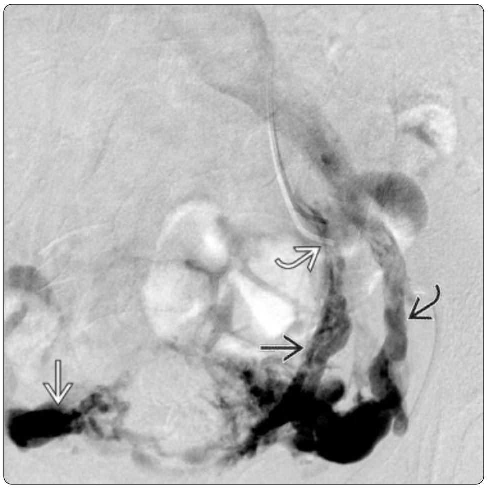


Transjugular Embolization (Left Ovarian Venography)

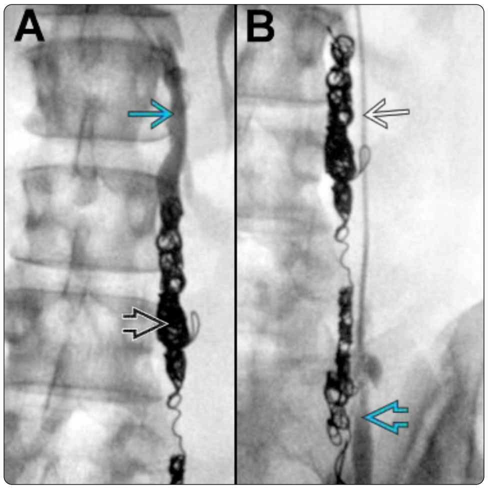


(Left) *An MPA catheter ➡ has been selectively placed in the left renal vein ⇨ via internal jugular access. DSA venography is performed to evaluate venous anatomy and to exclude or confirm ovarian vein reflux →; a Valsalva maneuver during the DSA may help to elicit reflux, which was present in this case.* **(Right)** *Catheter venography of the ovarian vein →[(A) cephalad and (B) caudal segments] is performed noting any collateral channels or duplicated segments ↪. The catheter ➡ is then advanced to pelvic level.*

Transjugular Embolization (Distal Left Ovarian Venography)

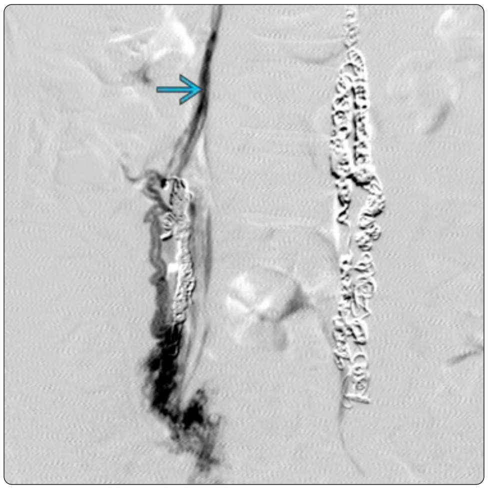


Transjugular Embolization (Transcatheter Coil Embolization)

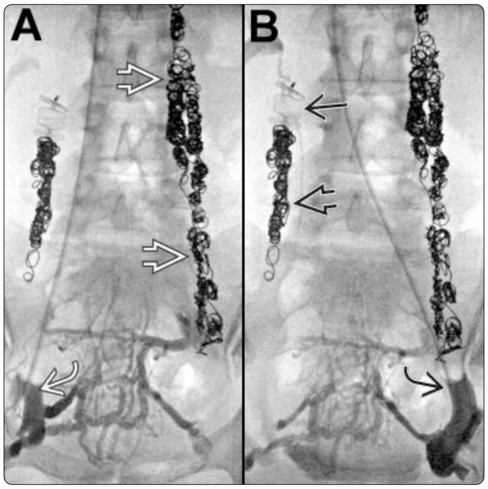


(Left) *DSA venogram with the catheter tip ↪ positioned caudally in the left ovarian vein → shows cross-pelvic filling of right varices ➡ as well as of the left internal iliac vein ↪. Because of the extensive venous drainage, sclerotherapy of the pelvic varices through the ovarian vein catheter would be ineffective.* **(Right)** *(A) Multiple embolization coils ⇨ have been placed in the main left ovarian vein trunk →. (B) After coiling the main trunk, the catheter ➡ is placed in the duplicated channel ⇨ for additional coil embolization.*

Transjugular Embolization (Right Ovarian Venography)



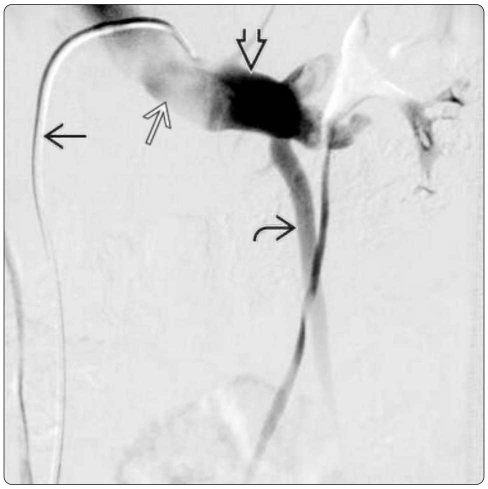
Transjugular Embolization (Postembolization Venogram)



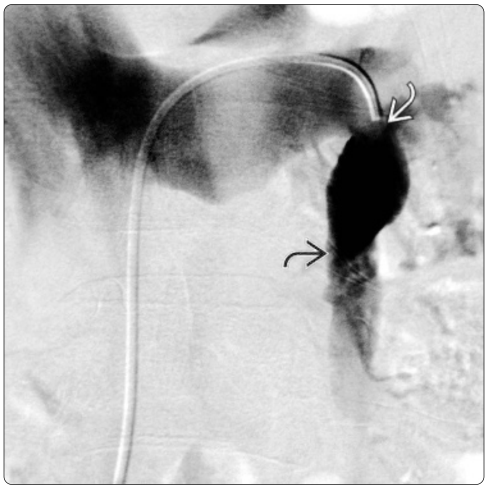
(Left) *After embolizing the left ovarian vein, the right ovarian vein → is catheterized and venography is performed, followed by embolization of the entire vein.* **(Right)** *After coil occlusion ⇨ of the entire left ovarian vein and combined coil ⇨ and plug occlusion → on the right, pelvic venography is performed with (A) an occlusion balloon catheter in the right internal iliac vein ↪ and (B) in the contralateral vein ↪. This again shows transpelvic filling of varicosities. Sotradecol sclerotherapy was performed via the balloon catheters.*

(Left) *A Cobra catheter → has been placed in the left renal vein ⇨ via transfemoral venous access. A venogram shows ovarian vein contrast reflux ↪, confirming valvular incompetency. Less dense contrast in the proximal renal vein ➩ is from extrinsic aortic compression, as the vein is retroaortic.* **(Right)** *With the catheter at the ovarian vein origin ↪, repeat venography again shows contrast reflux in a dilated ovarian vein ↪. The elevated hydrostatic pressure that occurs in a retroaortic renal vein contributes to the pathophysiology.*

Transfemoral Embolization (Initial Left Renal Venography)

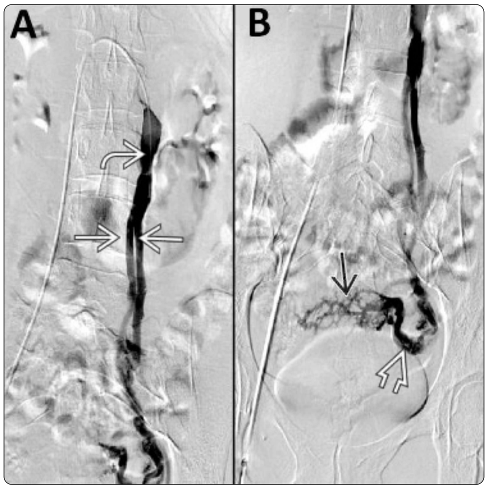


Transfemoral Embolization (Left Ovarian Vein Reflux)

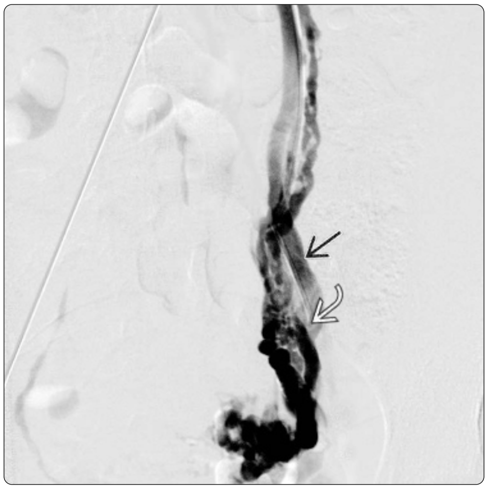


(Left) *(A) The catheter tip ↪ is advanced into the cephalad portion of the ovarian vein where venography of the upper venous segment is performed, showing duplicated channels →. (B) Caudal venography is also performed, showing pelvic ⇨ and periuterine → varices.* **(Right)** *The catheter tip ↪ is advanced caudally in one of the duplicated trunks → of the left ovarian vein. The coil diameters chosen for embolization are typically 3-5 mm larger than that of the target ovarian vein.*

Transfemoral Embolization (Selective Left Ovarian Venography)

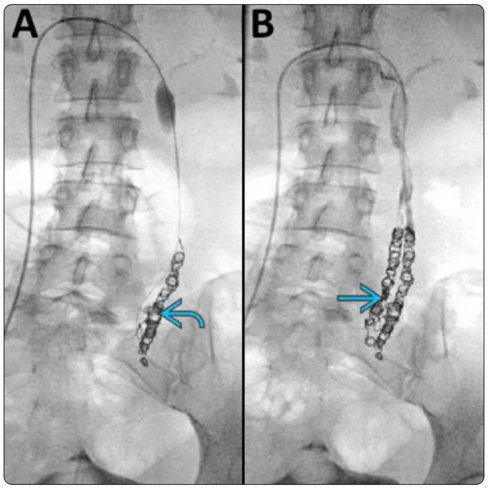


Transfemoral Embolization (Distal Left Ovarian Venography)

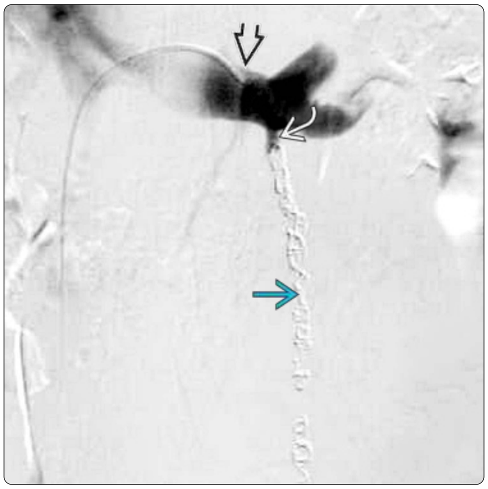


(Left) *When not alternating between coils and sclerosant, coil embolization of the entire ovarian vein is performed from the caudal extent to the vein confluence with the renal vein. Embolization of (A) the more lateral duplicated segment ↪ was performed initially, followed by embolization of (B) the more medial channel →.* **(Right)** *After embolizing the entire left ovarian vein →, a repeat left renal ⇨ venogram is performed, showing that the contrast enters only a tiny portion ↪ of the target vein.*

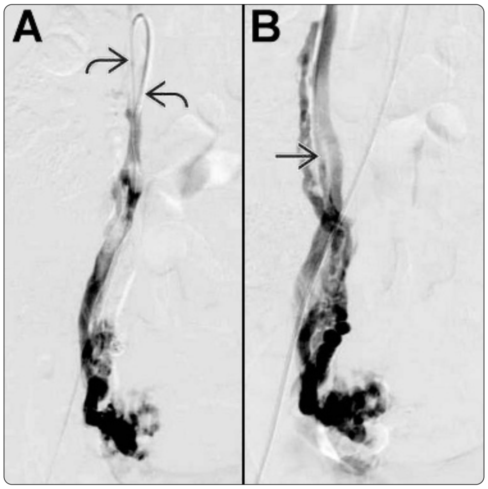
Transfemoral Embolization (Transcatheter Coil Embolization)



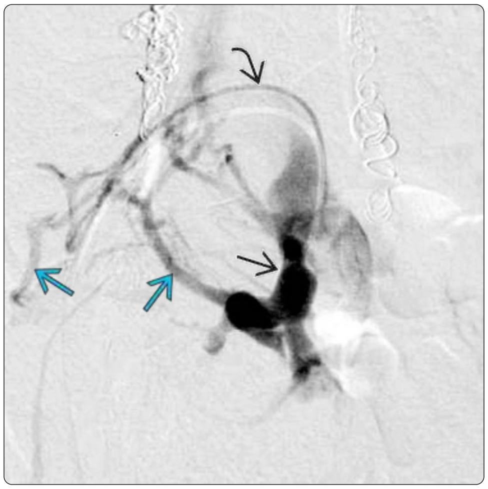
Transfemoral Embolization (Postembolization Venogram)



Transfemoral Embolization (Selective Right Ovarian Venogram)

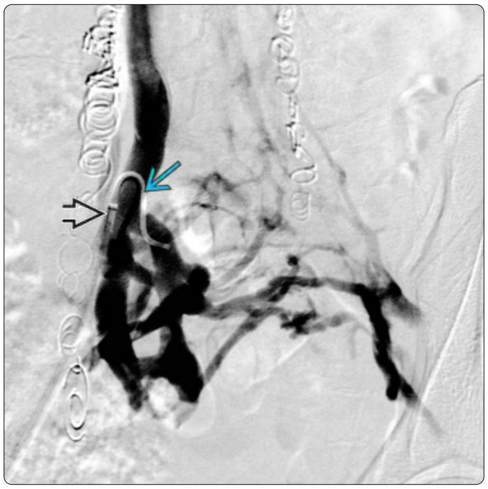


Transfemoral Embolization (Internal Iliac Venography)

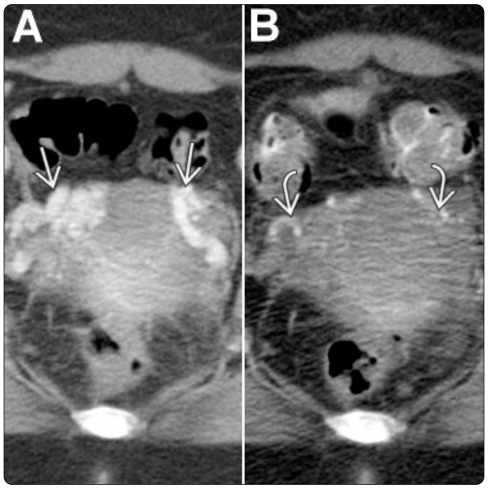


(Left) *(A) Femoral access right ovarian vein catheterization usually requires either a reverse curve catheter ↷ (e.g., Simmons) or a Waltman loop. (B) After catheterizing the vein, which arises off the IVC, a guidewire is advanced caudally, and the reverse curve catheter is exchanged for a straight catheter → for embolization.* **(Right)** *For internal iliac venography, a forward-facing catheter ↷ (e.g., Cobra) may be used to catheterize the contralateral internal iliac vein →. Venography shows cross-filling pelvic varices →.*

Transfemoral Embolization (Internal Iliac Venography)

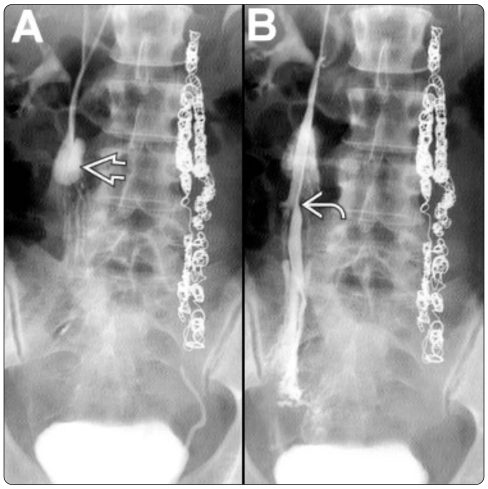


Transfemoral Embolization (Postembolization Results)

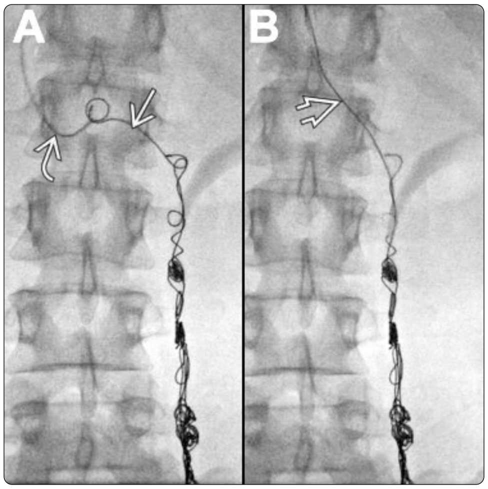


(Left) *Internal iliac venography ipsilateral to the femoral access site requires either a reverse curve catheter → or formation of a Waltman loop. Using a femoral venous access sheath ⇨ facilitates catheter exchanges during the procedure.* **(Right)** *CECT (A) before treatment shows large bilateral periuterine pelvic varices ⇨. (B) After combined bilateral ovarian vein coil embolization and bilateral internal iliac vein sclerotherapy, there are no longer any varices ↷ identified.*

Procedural Complication (Ovarian Vein Perforation)



Procedural Complication (Malpositioned Embolization Coil)



(Left) *Ovarian venogram shows (A) contrast extravasation ⇨ adjacent to the catheter tip, indicating ovarian vein perforation. With prompt recognition (B), a catheter ↷ can usually be negotiated beyond the perforation. Embolize the entire ovarian vein including the damaged segment.* **(Right)** *(A) An embolization coil ↷ extending from the ovarian vein into the left renal vein could potentially cause renal vein thrombosis. The cephalad end of the coil was captured with a snare ⇨ and (B) the coil was slowly ⇨ removed.*

Varicocele

KEY FACTS

TERMINOLOGY

- Normal testicular venous drainage
  - Pampiniform plexus → internal spermatic vein (ISV)
    - Left ISV → left renal vein
    - Right ISV → IVC (immediately inferior to right renal vein)
- Varicocele etiology
  - Internal spermatic vein valvular insufficiency/absence
- Laterality
  - 90% left, 1% right, 9% bilateral
    - Isolated right-sided varicocele mandates search for underlying pathology

PREPROCEDURE

- Varicoceles common (15%) and often asymptomatic
  - Indications for treatment
    - Pain, mass effect, bothersome appearance
    - Infertility
      - Treat if palpable, associated with abnormal semen parameters and female partner has normal fertility
    - Testicular atrophy in adolescent/pediatric patient

PROCEDURE

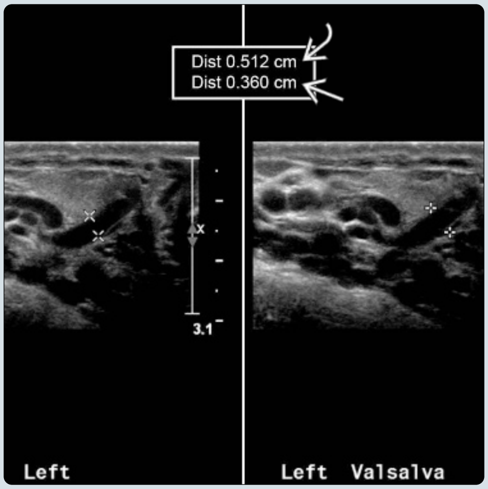
- Use low doses of sedation as patient needs to perform Valsalva maneuver on demand
- Radiation protection important
  - Avoid DSA
  - Avoid imaging over testicle
  - Use gonadal shield
- Combined coil and sclerosant embolization is preferred endovascular technique

OUTCOMES

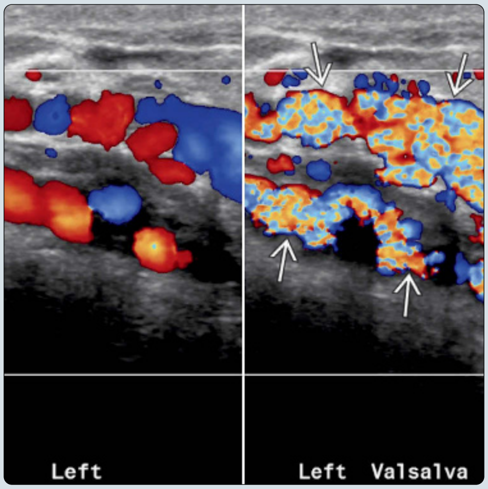
- 95% technical success
- 50% chance of improvement in semen parameters
- 30% rate of subsequent pregnancy
- 4% recurrent varicocele

(Left) *Grayscale ultrasound shows dilated serpiginous anechoic structures posterior to the left testes. Without Valsalva, they measure 3.6 mm in diameter →. With Valsalva, they measure 5.1 mm in diameter ↪.* **(Right)** *When the patient performs a Valsalva maneuver, there is augmentation of retrograde flow →. Ultrasound diagnosis of Varicocele includes diameter > 2 mm and augmentation with Valsalva.*

Grayscale Ultrasound of Varicocele

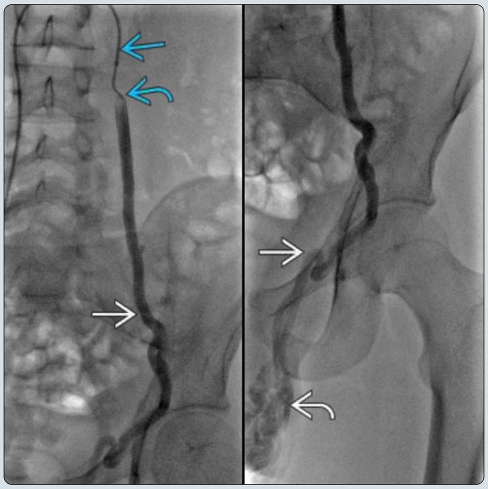


Color Doppler Ultrasound of Varicocele

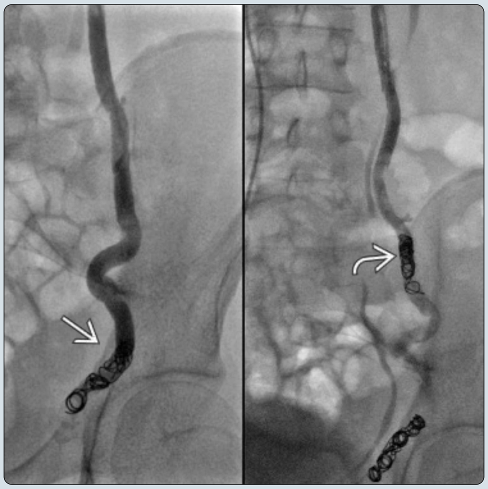


(Left) *After a 7-Fr sheath is placed in the right CFV, a 7-Fr gonadal guiding catheter is placed into the ISV →, through which a 5-Fr Berenstein catheter ↪ is placed. A venogram performed during Valsalva shows abnormal caudal/retrograde flow through the ISV → into the dilated pampiniform plexus ↪.* **(Right)** *A combination of coils and 2% STS are used to embolize the ISV. The 1st coil mass → is placed at the internal ring of the inguinal canal. The 2nd coil mass is placed at the level of the SI joint ↪.*

Initial ISV Venogram Prior to Embolization



Combined Coil and STS Embolization



TERMINOLOGY

Definitions

- **Anatomy**
  - Normal testicular venous drainage
    - Pampiniform plexus → internal spermatic vein (ISV)
    - Left ISV → left renal vein
      - Anatomic variants of left ISV in 10-20% of cases (multiple gonadal vein branches draining into left renal vein)
    - Right ISV → IVC (anterior-lateral, immediately inferior to right renal vein)
      - Anatomic variants of right ISV in 20-25% of cases (multiple branches, one of multiple branches draining into right renal vein)
    - ISV a.k.a. gonadal vein and testicular vein
    - Panpifiform plexus a.k.a. spermatic venous plexus
  - Alternative drainage pathways
    - Become primary drainage of testicle with ISV reflux and after embolization
      - External pudendal vein → greater saphenous vein
      - Cremasteric vein (a.k.a. external spermatic vein) → inferior epigastric vein
      - Ductus deferens vein → superior vesicular vein → internal iliac vein
- **Varicocele etiology**
  - Internal spermatic vein valvular insufficiency/absence
- **Infertility etiology in presence of varicocele**
  - Elevation of testicular temperature
  - Alternative hypotheses less likely
    - Reflux of toxic metabolites
    - Hypoxia from venous stasis
  - Most common abnormality in infertile men
    - Seen in 40% of infertile men, only 15% general male population
    - However, 75% of men with varicocele have normal fertility

PREPROCEDURE

Indications

- Symptomatic varicocele
  - Pain, mass effect, bothersome appearance
- Infertility (all 3 criteria should be met)
  - Palpable varicocele
    - Nonpalpable have no proven impact on fertility
  - Abnormal semen parameters
    - Sperm morphology, decreased motility/count
  - Female partner has normal fertility
- Testicular atrophy in adolescent/pediatric patient
- Varicoceles are common (15%) and often asymptomatic
  - Treat only for indications above

Contraindications

- Active infection
- Severe contrast allergy

Preprocedure Imaging

- **US**
  - > 2 mm in diameter; flow reversal/augmentation with Valsalva
- **CT**
  - Rarely needed
  - Can be used to evaluate for underlying pathology in isolated right-sided varicocele
    - Caval thrombosis
    - Pelvic or retroperitoneal mass
  - Can show Nutcracker phenomena, which can contribute to left-sided varicocele
    - Compression of left renal vein between aorta/SMA

Getting Started

- Things to check
  - Laterality
    - 90% left sided
    - 1% right sided
      - Isolated right-sided varicocele requires search for underlying pathology
      - Caval thrombosis
      - Right gonadal vein compression by retroperitoneal mass/lymph nodes
    - 9% bilateral
  - History
    - Symptoms: Pain, testicular atrophy, infertility
      - Infertile patients: Preprocedural semen analysis
    - Prior varicocele treatment
  - Physical examination
    - Perform supine and standing
    - Perform with and without Valsalva
  - Allergies
    - Medications, contrast, latex
  - Pertinent medication history
    - Anticoagulants, antiplatelet agents, oral hypoglycemic agents
  - Laboratory parameters
    - May forgo pre-procedure lab evaluation
      - Typically healthy young patients
    - If labs available prefer
      - INR < 1.8; platelet count > 50,000/μL
      - eGFR > 45
  - Consent for procedure
    - Discuss potential thrombophlebitis (< 5%), varicocele recurrence (< 4%), inability to treat, vessel injury, nontarget embolization, contrast-induced nephropathy, procedure-related pain
- Medications
  - Intraprocedural conscious sedation
    - Low doses as patient needs to perform Valsalva maneuver on demand
  - 1-2% lidocaine local anesthesia
  - Preprocedural ketorolac (Toradol 15-30 mg IV) optional
- Equipment list
  - Catheters
    - Selective catheters for femoral approach
      - Left ISV: 7-Fr Hopkins-customized gonadal guiding catheter
      - Right ISV: Reverse curve catheters (Simmons 1)
    - Selective catheters for jugular approach
      - Left ISV: Cobra-1
      - Right ISV: Multipurpose angled (MPA), Headhunter
    - Microcatheters

Clinical Grading Scale for Varicoceles

Grade	Ultrasound	Palpable	Visible
Grade 0	+	- (even with Valsalva)	-
Grade 1	+	+ (only with Valsalva)	-
Grade 2	+	+ (even without Valsalva)	-
Grade 3	+	+	+

Proposed by Dubin and Amelar; grade 0 referred to as subclinical varicocele.

Dubin L et al: Varicocele. Urol Clin North Am. 5(3):563-72, 1978.

            - Rarely needed for left varicocele
            - Required for right-sided varicocele embolization
    - Coils
        - Pushable
        - Oversize by 20%
        - Typically 4-10 mm diameter
        - Left: 0.035" (use 4- or 5-Fr catheter)
        - Right: 0.018" typically (need micro-catheter)
    - Sclerosants
        - 2% sodium tetradecyl sulfate (STS) foam preferred
            - Mix 2 mL 3% STS with 1 mL normal saline
            - Mix above with 3 mL air
            - Agitate/mix vigorously
    - Gonadal shield

PROCEDURE

Patient Position/Location

- Patient supine
- Approach operator dependent
    - Transfemoral venous approach
    - Internal jugular vein approach

Procedure Steps

- **Procedure-specific goals**
    - Evaluate bilateral ISV for evidence of reflux/valve incompetence & varicocele
    - Completely embolize involved ISV
- Obtain venous access (jugular or femoral vein)
    - Introduce chosen guiding or selective catheter
    - Selectively catheterize target internal spermatic vein
- Internal spermatic venography
    - Left ISV
        - Selectively catheterize left renal vein
            - Femoral approach: Hopkins guiding catheter and 5-Fr Berenstein
            - Jugular approach: Cobra/MPA/H-1
        - Advance catheter beyond orifice of left ISV
            - If ISV not visualized, perform left renal vein venogram with reverse Trendelenburg/Valsalva
    - Right ISV
        - Selectively catheterize ISV
            - Femoral approach: Reverse curve catheter (Simmons 1 or 2)
            - Jugular approach: Cobra/MPA/H-1
        - Enters IVC anterolaterally below right renal vein
    - Perform ISV venography
        - 10-20 mL contrast injection during Valsalva maneuver
        - Image from ISV origin to pubic symphysis
            - Careful attention to gonadal shielding/dose
            - Only use DSA if necessary
- **Embolotherapy**
    - **Combined coil and STS embolization (preferred method)**
        - Mix STS solution as above
        - Initial coil placed at internal ring of inguinal canal
            - Bony landmark: Superior pubic ramus
            - Venous landmark: Where vein transitions from vertical to oblique
        - Oversize coil by 20%
            - Tight packing not desired at this point
            - Typically 6-8 mm in diameter
            - Patient Valsalva while deploying coils
        - Negotiate 5-Fr catheter inferior to coil after deployment, if possible
            - Inject contrast during Valsalva
            - Note volume of contrast injected to reflux into upper portion of pampiniform plexus
            - Base volume of STS injection on prior contrast injection and displacement of static contrast
            - Previous concerns regarding STS reflux into the testicle now largely ignored
            - Volume typically 4-6 mL
            - Coil forces STS to stay inferiorly
        - Retract 5-Fr catheter into coil mass
            - Add additional coils into coil mass to allow for tighter packing
            - May use smaller coils than first coil to achieve tighter packing
        - Retract 5-Fr catheter above coil mass
            - Perform venography during Valsalva to ensure occlusion
            - If large collaterals seen, perform additional embolization
        - Retract 5-Fr catheter to level of upper SI joint
            - Deploy single coil at this level
            - Oversize by 20%
            - Tight packing not desired at this point
            - Valsalva during coil deployment
        - Negotiate 5-Fr catheter distal to this coil, if possible
            - Inject contrast during Valsalva to fill space between 2 coil masses
            - Inject STS during Valsalva (typical volume 2 mL)
            - Base volume of STS injection on prior contrast injection and displacement of static contrast
        - Retract 5-Fr catheter back into coil mass at SI joint

            - Add additional coil(s) for tighter packing
            - Smaller size may help achieve tighter packing
        - Retract 5-Fr catheter above coil mass at SI joint
            - Perform venography during Valsalva
            - Ensure occlusion/no reflux
            - If collaterals seen, perform additional embolization
        - Conclude procedure
            - Remove sheath, guiding catheter and 5-Fr catheter
            - Achieve hemostasis, dress venipuncture site
    - **Coil only**
        - Can be significantly more costly than coil and STS embolization
        - Position catheter in distal ISV just above pubic symphysis
            - Coil from this point proximally to ISV origin
            - Completely occlude entire length of ISV
        - If large collaterals identified, selectively catheterize and embolize
        - Small parallel collaterals remain patent and could enlarge over time, leading to recurrent varicocele
    - **n-BCA glue**
        - Injection of n-BCA via microcatheter positioned at sacroiliac joint level
            - Flush catheter with 5-10% dextrose (nonionic) solution before/after delivery (avoids glue consolidation in microcatheter lumen)
        - Prior operator experience with n-BCA strongly encouraged
            - Nontarget embolization possible
            - Delivery catheter can become glued into vessel being embolized

Alternative Procedures/Therapies

- Surgical
    - Microsurgical subinguinal ligation
        - Current preferred surgical approach
            - 2% recurrent varicocele; < 1% hydrocele formation
            - Fastest recovery time of surgical approaches
            - Highest reported subsequent pregnancy rates
    - Microsurgical inguinal ligation
        - 10% recurrent varicocele; < 1% hydrocele formation
    - Open surgical ligation
        - High retroperitoneal ligation (Palomo)
            - Ligation of ISV between anterior superior iliac spine and renal vein
            - May ligate testicular artery or lymphatics
            - 12.5% recurrent varicocele; 8% hydrocele
    - Laparoscopic varicocelectomy
        - Ligation of ISV near entry into left renal vein
        - Testicular artery separate from ISV (spared)
        - 11% recurrent varicocele; 8% hydrocele
    - Surgical complications
        - Hydrocele
            - Secondary to accidental ligation of lymphatics
        - Recurrent varicocele
            - Incomplete ligation of collateral venous channels

POST PROCEDURE

Things to Do

- Postprocedure bedrest
    - Femoral vein access: 2 hours
    - Jugular vein access: 1 hour
- Pain control: Nonsteroidal antiinflammatory agents
- Patient instructions
    - No heavy lifting or significant exertion for 48 hours
    - Mild to moderate testicular pain not unexpected
- Clinic follow-up at 3 months
    - Ultrasound
    - Repeat semen evaluation (if done for infertility)

OUTCOMES

Complications

- Most feared complication(s)
    - Embolization of coils into lungs (rare)
- Immediate/periprocedural complication(s)
    - ISV perforation
        - Caused by catheter/guidewire manipulations
        - Rarely clinically significant, but can obscure catheter placement
        - May necessitate aborting procedure and re-attempting in 1-2 weeks
- Delayed complication(s)
    - Pampiniform plexus thrombophlebitis
        - Occurs in up to 5% of patients, usually self-limited
        - Treat with NSAIDs
- Other complications
    - 4% recurrent varicocele
        - Subsequent dilatation of untreated collaterals
        - High rate of recurrence with underlying Nutcracker syndrome
    - 0% hydrocele

Expected Outcome

- Technical success (90-97%)
    - Lower success rates if varicoceles fed by aberrant collaterals
- Semen parameter improvement (27-75%)
    - Takes 3 months to see changes
        - Length of spermatogenesis
- Pregnancy rate (12-40%)
- Quicker recovery rate compared with surgical alternatives

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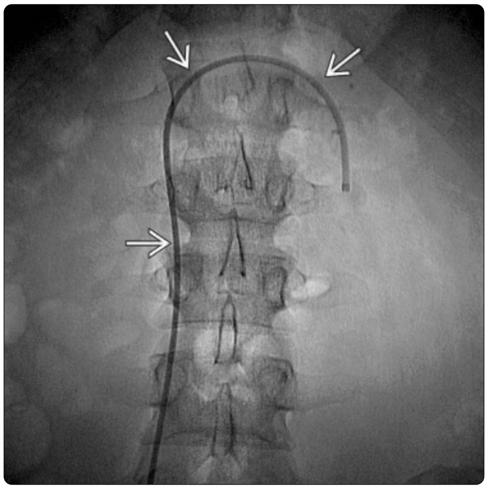
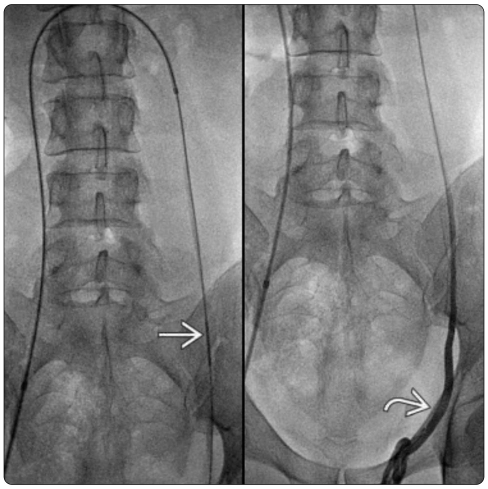
10. Cayan S et al: Treatment of palpable varicocele in infertile men: a meta-analysis to define the best technique. J Androl. 30(1):33-40, 2009

(Left) *Access is obtained to the right CFV. A 7-Fr sheath is placed. Through this, a 7-Fr gonadal guiding catheter ➡ and a 5-Fr 100 cm long Berenstein are placed. The gonadal guiding catheter will typically engage the ISV with minimal manipulation.* **(Right)** *After venogram confirming placement in the ISV, the 5-Fr catheter ➡ is manipulated more distally. Repeat venogram is done. Internal ring of the inguinal canal is present at the level of the pubic symphysis and also where the ISV becomes more oblique ↪.*

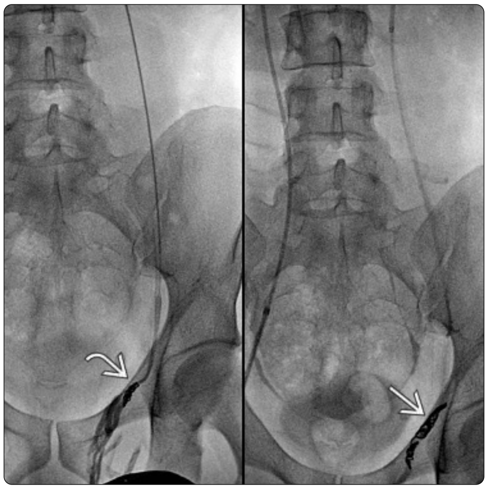


Step-By-Step: Coil and STS Embolization (Guiding Catheter Positioning)

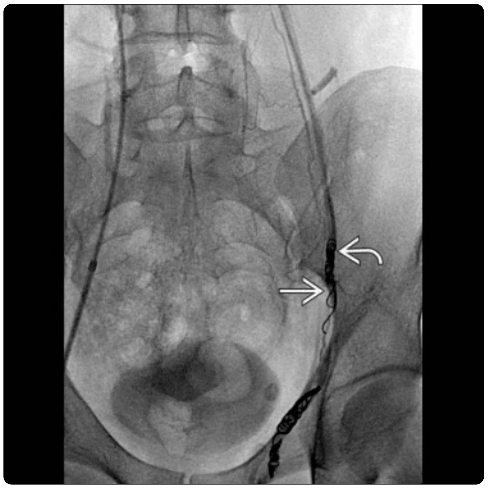


Step-By-Step: Coil and STS Embolization (Selective Venography)

(Left) *An initial coil is placed at the internal ring of the inguinal canal ↪. The 5-Fr catheter is then negotiated beyond the coils, and STS is injected while the patient Valsalvas using the contrast displacement method. Additional coils ➡ are then placed for more complete embolization.* **(Right)** *The 5-Fr catheter is retracted to the level of the SI joint ➡. One coil is placed. The 5-Fr catheter is negotiated distal to this coil, and STS is injected. The catheter is retracted, and more coils are then placed for tighter packing ↪.*

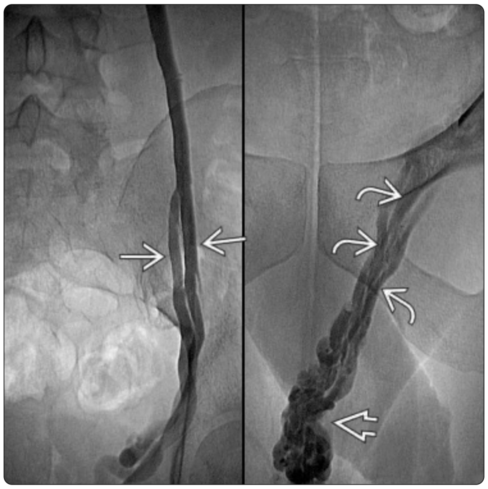


Step-By-Step: Coil and STS Embolization (Initial Coil Placement)

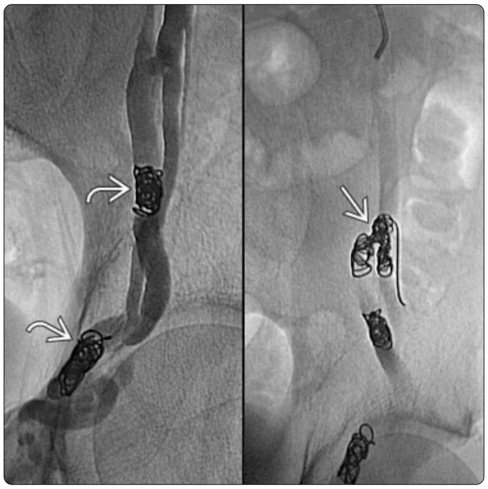


Step-By-Step: Coil and STS Embolization (Continue Treatment)

(Left) *Multiple parallel channels of the ISV are commonly encountered during venography. It is necessary to embolize all feasible channels. 2 parallel channels are present in the inferior ISV ➡, 3 within the inguinal canal ↪, and the pampiniform plexus ⇨ is dilated.* **(Right)** *(A) Both of the more superior channels were individually selected and embolized with coils ↪ and STS. (B) Additionally, another coil ➡ was deployed, straddling the confluence of these channels more superiorly.*

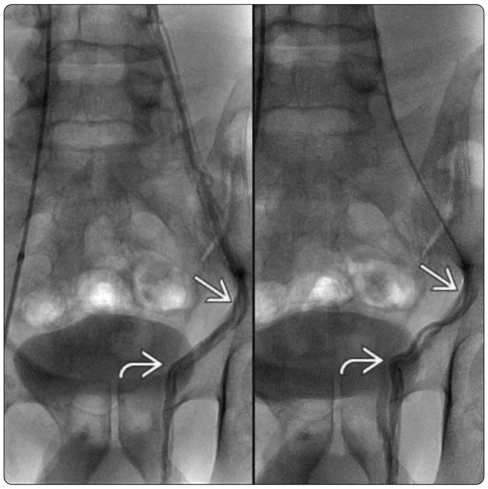


Parallel Channels (Before Embolization)

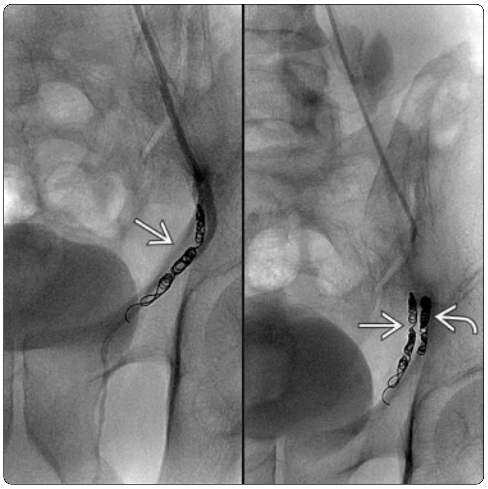


Parallel Channels (After Embolization)

Bilateral Varicocele Embolization (Left Venogram)

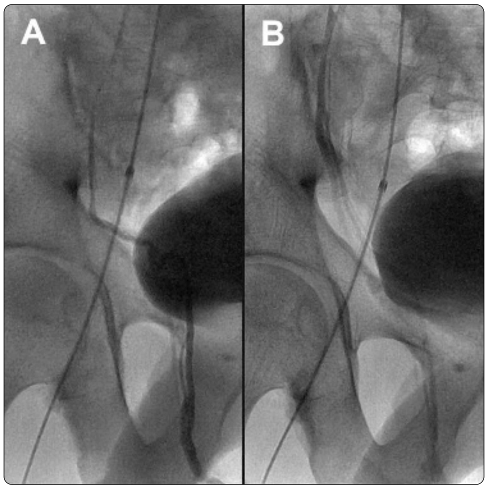


Bilateral Varicocele Embolization (Left Treatment)

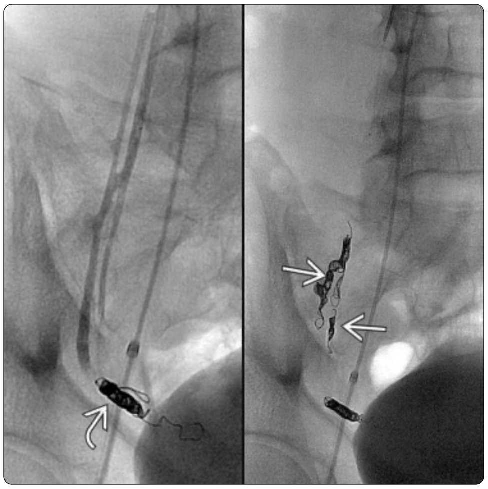


(Left) *Bilateral varicoceles occur in 9% of patients. Unlike isolated right-sided varicoceles, no search for underlying pathology is required. Initial proximal (A) and more distal (B) ISV venography shows the level of the internal* ➡ *and external* ↪ *inguinal rings and multiple parallel channels.* **(Right)** *Left-sided varicocele embolization is performed using the sandwich STS and coil* ➡ *technique, being mindful to embolize parallel* ↪ *channels. Varicoceles will persist/recur if all channels are not addressed.*

Bilateral Varicocele Embolization (Right Venogram)

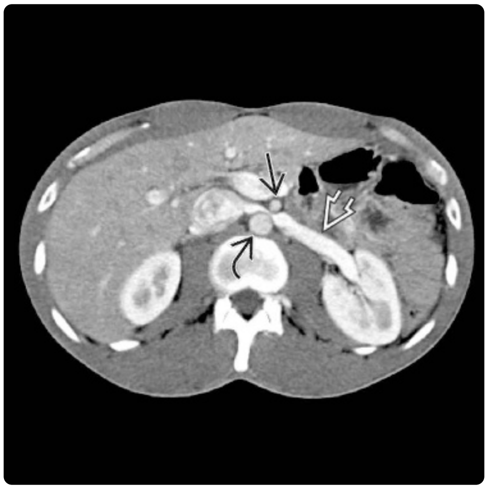


Bilateral Varicocele Embolization (Right Treatment)

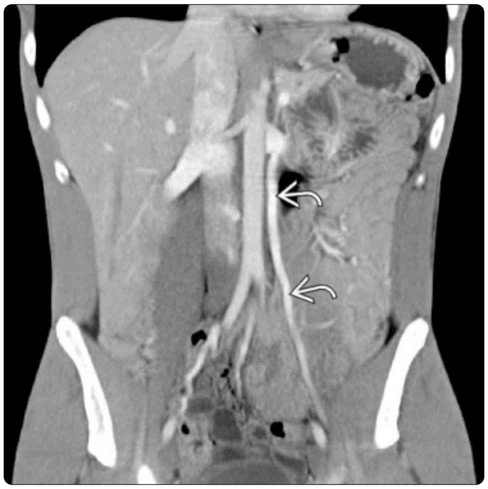


(Left) *The right ISV joins the IVC at an anterolateral position just inferior to the right renal vein. Selection from the groin is accomplished using a reverse curved catheter (Simmons 1 or 2). Initial (A) and more distal (B) ISV venograms show abnormal reflux of contrast caudally.* **(Right)** *Microcatheters and microcoils are often required for right-sided varicocele embolizations. Coils have been* ↪ *placed at the internal ring of the inguinal canal, followed by embolization* ➡ *of parallel channels.*

Nutcracker Syndrome (Axial View)



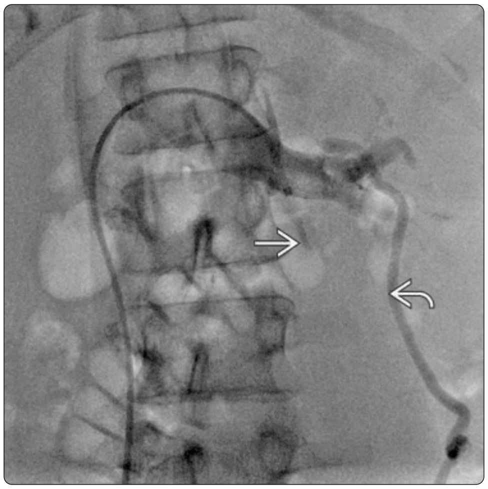
Nutcracker Syndrome (Coronal View)



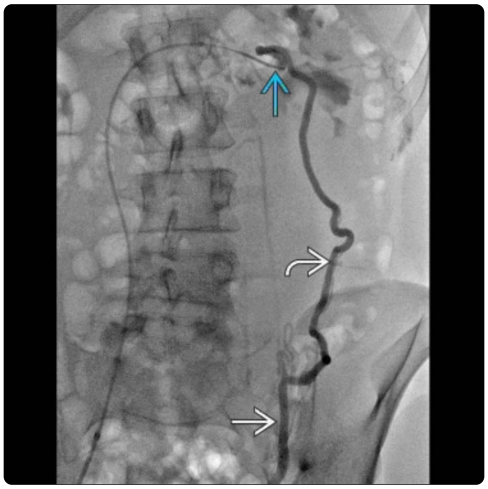
(Left) *Symptomatic extrinsic compression of the left renal vein* ➡ *between the aorta* ⇨ *and the SMA* → *(a.k.a. Nutcracker syndrome) can result from a reduced angle between the SMA and aorta.* **(Right)** *Symptoms of Nutcracker syndrome include left flank pain, recurrent macroscopic hematuria, and left-sided varicocele* ↪*. Even in patients without Nutcracker syndrome, compression of the left renal vein by the SMA may cause elevated pressures in the left renal vein, explaining left-sided varicocele predominance.*

(Left) *Left renal venography during Valsalva and with 12° reverse Trendelenburg shows only minimal reflux into the proximal ISV* ➡*, consistent with a competent valve. However, a refluxing left renal capsular collateral was identified* ↪*.* **(Right)** *Attempts to cross the proximal valve of the ISV were unsuccessful. The renal capsular collateral vein* ↪ *was selected using a 5-Fr Berenstein catheter* ⇨*, and venography was performed confirming communication with the inferior ISV* ➡ *and a moderate-sized varicocele (not shown).*

Refluxing Left Renal Capsular Collateral (Renal Venogram)

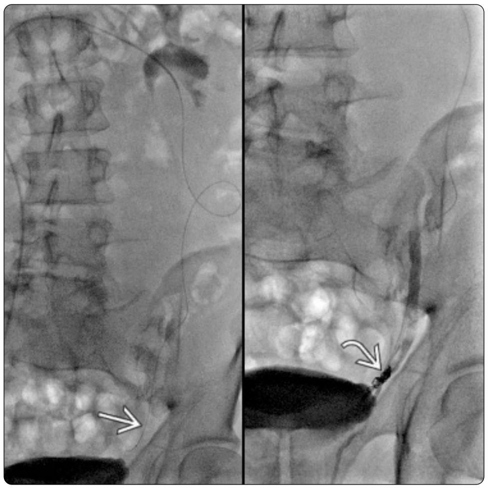


Refluxing Left Renal Capsular Collateral (Capsular Venogram)

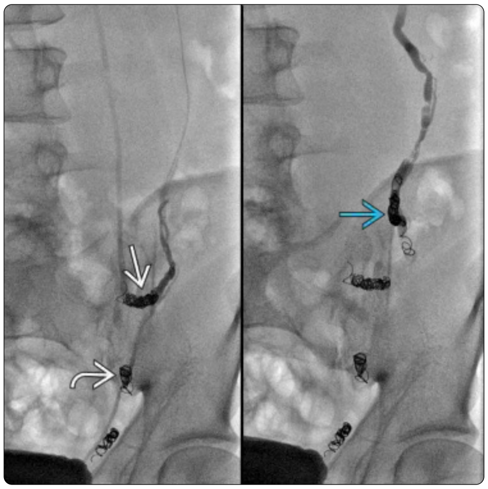


(Left) *Given the tortuosity of this vessel, a Renegade catheter and 0.018" GT Glidewire were used to navigate distally* ➡ *to the level of the internal inguinal ring. At this level, a 6-mm 0.018" coil* ↪ *was placed, and 1 mL of 2% STS was injected.* **(Right)** *Coils and STS were placed/injected in the more proximal ISV proper* ↪*, followed by coil embolization of the junction between the renal capsular collateral and the ISV* ➡*. Further coil and STS injection of the renal hilar collateral was then performed* ⇨*.*

Refluxing Left Renal Capsular Collateral (Initial Coil Placement)

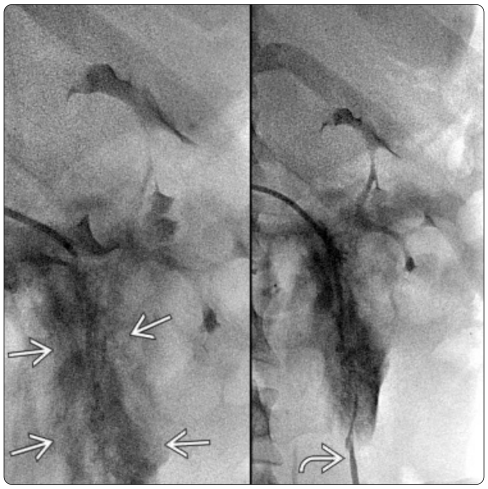


Refluxing Left Renal Capsular Collateral (Additional Embolization)

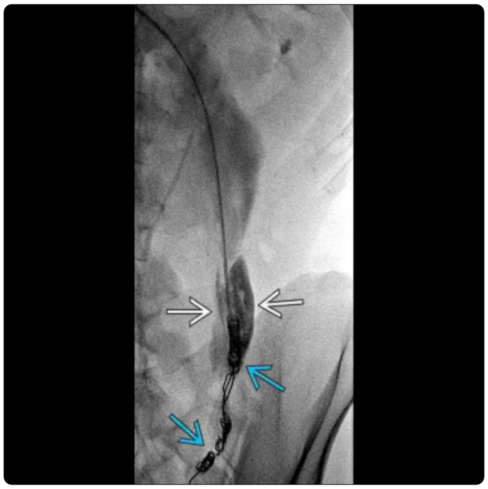


(Left) *During attempted selection of the left ISV, perforation occurred, confirmed by contrast extravasation* ➡*. On repeat venogram, the ISV was identified* ↪*.* **(Right)** *Despite extravasated contrast, the distal ISV was able to be cannulated and coils* ⇨ *were placed. Additional ISV perforation occurred more inferiorly* ➡*. ISV perforation does not typically result in clinical consequences (e.g., retroperitoneal hematoma or significant blood loss), but extravasated contrast can obscure the target vessel(s).*

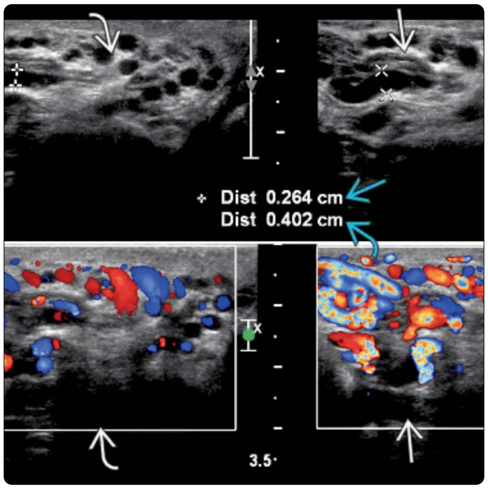
ISV Perforation



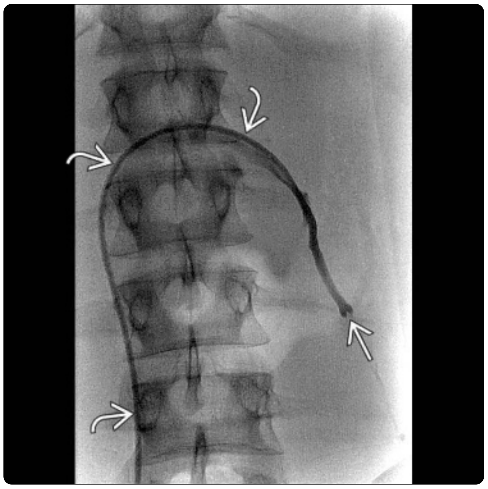
ISV Perforation



Varicocele Embolization (Initial Ultrasound)

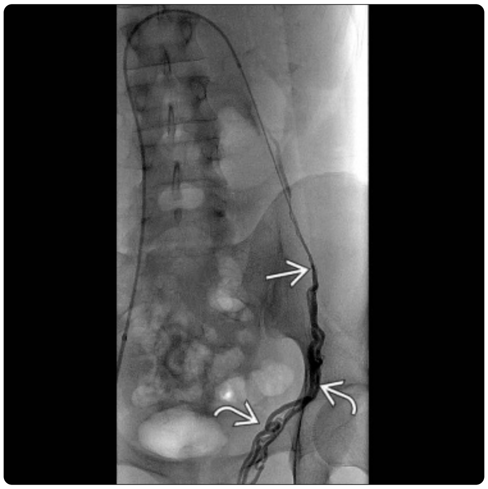


Varicocele Embolization (Initial ISV Venogram)

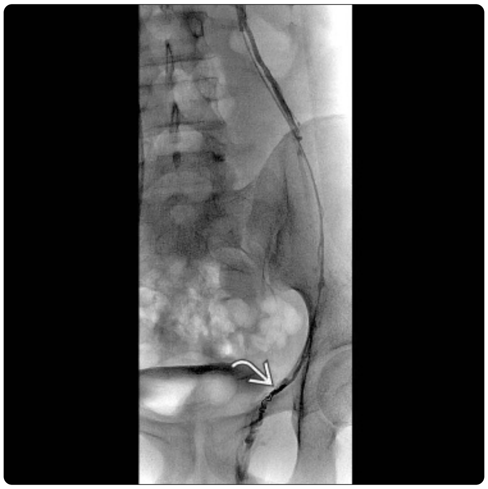


(Left) *Initial US without ↪ and with → Valsalva shows a dilated pampiniform plexus, which enlarges with Valsalva. Color Doppler confirms augmentation with Valsalva. The diameter is 2.6 mm without Valsalva → and 4.0 mm with Valsalva ↪.* **(Right)** *After placement of a 7-Fr gonadal guiding catheter ↪, ISV venogram shows no reflux inferiorly into the pampiniform plexus secondary to a competent valve →.*

Varicocele Embolization (Subsequent Venogram)

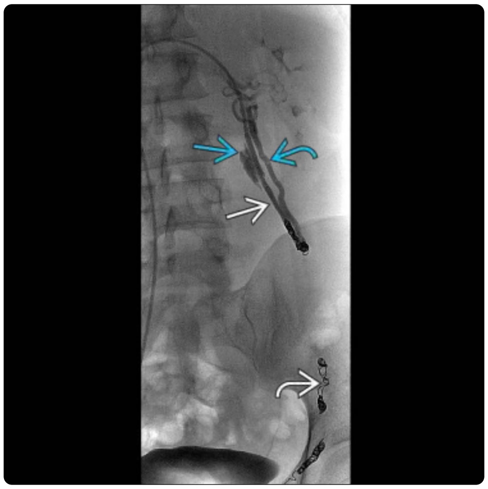


Varicocele Embolization

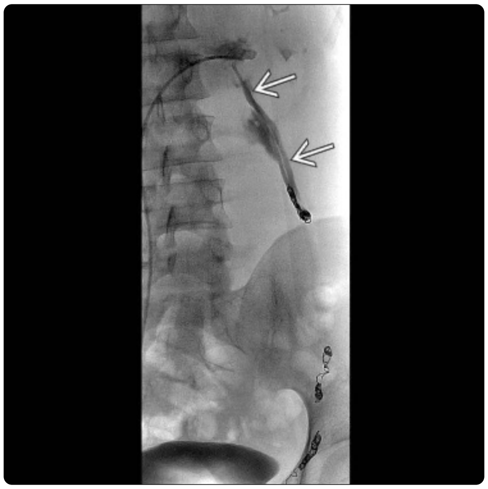


(Left) *Given patient's symptoms (testicular atrophy and pain), further intervention was warranted. A Glidewire and glidecatheter → were negotiated beyond the competent valve. Venogram in the mid ISV confirmed reflux inferiorly ↪, indicating collateral reflux filling the mid and inferior portions of this vein. Multiple parallel channels are seen.* **(Right)** *2% STS foam was injected during Valsalva using the contrast displacement method. A single 4-mm coil ↪ was placed at the internal inguinal right.*

Varicocele Embolization



Varicocele Embolization (Final Venogram)



(Left) *Further 4- and 6-mm coils as well as STS were placed more superiorly, with the 2nd coil mass ↪ placed in a parallel channel. Further coils were placed at the junction of the competent ISV → and the refluxing renal hilar collateral ↪. Note the small amount of extraluminal contrast → from attempts at crossing the competent valve in the ISV.* **(Right)** *Left renal venogram was then performed demonstrating reflux in upper portion of the renal hilar collateral vein → without contrast extending inferiorly beyond the upper coils.*

Venous Sampling and Venography: Renal and Adrenal

KEY FACTS

PREPROCEDURE

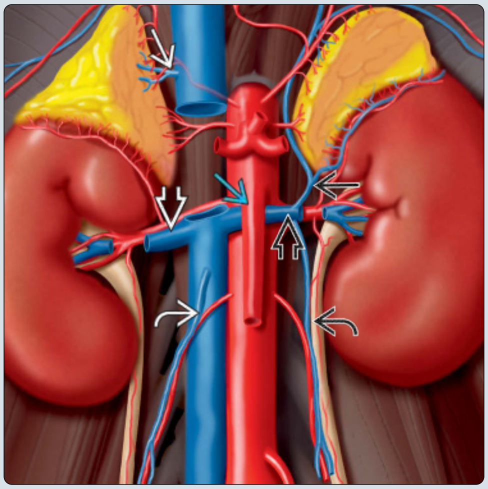
- **Adrenal venography/venous sampling**
    - For identification of 1° aldosteronism and localization of aldosterone-producing adenoma
    - Confirm adrenal gland as excess cortisol source in Cushing syndrome with adrenal mass on imaging
- **Adrenal vein anatomy**
    - In most individuals, each gland has single vein
    - Right adrenal vein drains directly inferior vena cava (IVC)
    - Left adrenal vein drains into left renal vein (LRV)
- **Renal venography/venous sampling**
    - Renal venography now usually associated with therapy (e.g., gonadal vein embolization)
    - Infrequent use in renovascular hypertension diagnosis
- **Renal vein anatomy**
    - Usually each kidney drained by single renal vein; LRV courses anterior to aorta, posterior to superior mesenteric artery, joins IVC opposite right renal vein
    - Right renal vein shorter than left; joins IVC at L2

PROCEDURE

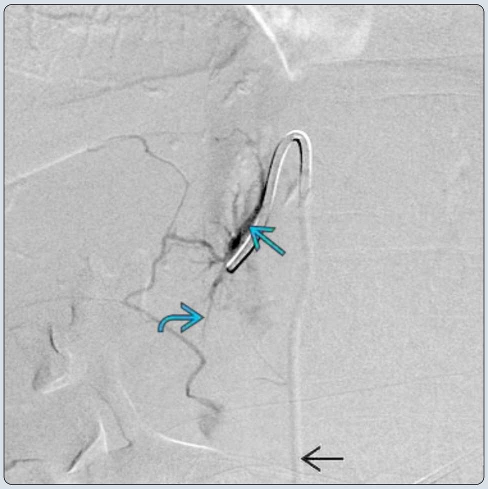
- **AVS**
    - Right adrenal vein more difficult to catheterize than left; should be catheterized/sampled 1st
    - If stimulating, obtain samples from each adrenal vein before and after adrenocorticotrophic hormone (ACTH) administration (1° hyperaldosteronism)
    - High aldosterone:cortisol ratio before and after ACTH, lateralizing to affected adrenal gland
    - Elevated cortisol lateralizing to adrenal vein in presence of adrenal mass on CT/MR confirmatory of endogenous Cushing syndrome
- **Renal venography/venous sampling**
    - LRV entrapment syndrome = nutcracker
        - Consider conservative treatment (6 months adult, 2 years if < 18 years old) prior to stenting

(Left) *Graphic shows that the right adrenal ➡, renal ➡, and gonadal ➡ veins drain directly into the inferior vena cava (IVC); the left adrenal ⇨ and gonadal ⇨ veins drain into the left renal vein (LRV) ⇨, which courses anterior to the aorta. LRV extrinsic compression can occur where the LRV passes between the SMA ⇨ and aorta.* **(Right)** *Right adrenal vein main trunk ⇨ and tributaries ⇨ are seen following gentle injection of 3-cc contrast through a reverse curve catheter (Mikaelsson) ⇨.*

Renal and Adrenal Vein Graphic

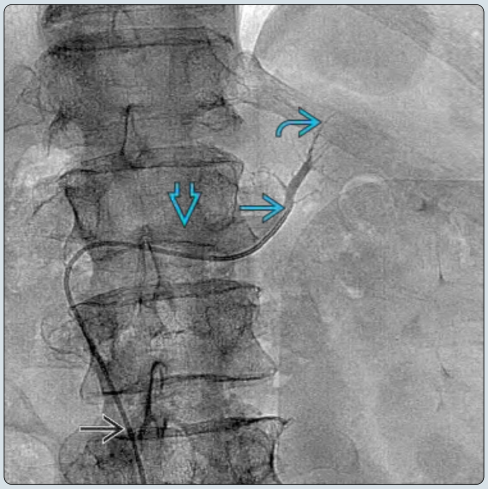


Right Adrenal Vein (Digitally Subtracted Angiographic Appearance)

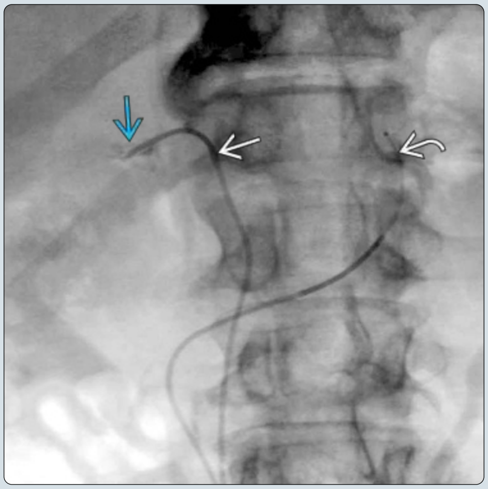


(Left) *A Simmons 2 catheter ⇨ was advanced into the LRV and withdrawn until the catheter tip engaged the left adrenal vein. Left adrenal vein main trunk ⇨, tributaries ⇨, and barely perceptible LRV ⇨ are seen following gentle injection of 3-cc contrast through the catheter.* **(Right)** *Simultaneous cannulation of right and left adrenal veins with contrast highlighting the right adrenal vein ⇨ is shown. A renal-double curve catheter ➡ engaged the right adrenal vein, and a coaxial microcatheter ➡ engaged the left adrenal vein.*

Left Adrenal Vein (Native Angiographic Appearance)



Simultaneous Adrenal Vein Sampling



TERMINOLOGY

Synonyms

- Adrenal vein sampling (AVS), renal vein sampling (RVS), renal vein renin sampling (RVRS), renin venous renin lateralization ratio (RVRR)
- Nutcracker syndrome (NCS) = left renal vein (LRV) entrapment syndrome

Definitions

- **Primary aldosteronism**: Hypersecretion of aldosterone by adrenal glands
    - 2/3 caused by unilateral aldosterone-producing adenoma (APA), i.e., Conn syndrome
        - Treated with unilateral adrenalectomy
        - 2% of cases have bilateral APA
    - 1/3 caused by bilateral idiopathic adrenal hyperplasia, i.e., idiopathic hyperaldosteronism
        - Treated with lifelong mineralocorticoid receptor blocker (spironolactone)
- **Cushing syndrome**: Clinical complex resulting from prolonged inappropriate exposure to glucocorticoids
    - Most frequently caused by administration of exogenous glucocorticoids or adrenocorticotrophic hormone (ACTH)
    - Endogenous causes include ACTH-secreting pituitary tumor, adrenal neoplasm (benign or malignant), or ectopic ACTH secretion by tumor
- **NCS**: Symptomatic extrinsic compression of LRV
    - Associated with pelvic congestion syndrome/varicocele
    - Nutcracker phenomenon: LRV compression in asymptomatic patient

Adrenal Vein Anatomy

- In most individuals, each gland has single main vein
    - Multiple adrenal veins occasionally occur
    - Adrenal veins communicate with retroperitoneal and renal capsular veins
- Right adrenal vein drains directly into posterolateral aspect of inferior vena cava (IVC)
    - Typically located 2-4 cm above right renal vein
    - Small accessory hepatic vein may rarely drain into right adrenal vein or vice versa (10% incidence)
- Left adrenal vein drains into superior aspect of LRV
    - Typically located 3-5 cm from LRV orifice
    - May very rarely drain directly into IVC

Renal Vein Anatomy

- Usually each kidney is drained by single renal vein
    - Renal veins rarely have valves
    - Communicate with other retroperitoneal veins (e.g., lumbar, azygos, gonadal veins)
- LRV courses between the aorta and overlying superior mesenteric artery to join IVC
    - LRV drains somewhat anteriorly into IVC
- Right renal vein is shorter, drains into IVC at ~ L2 vertebral level
- Frequent variations in renal venous anatomy
    - Anterior NCS: Compression between aorta and superior mesenteric artery
    - Posterior NCS: Compression of retroaortic LRV between aorta and vertebral column

PREPROCEDURE

Indications

- **AVS**
    - When confirmed, endocrine disorder requires localization to guide treatment
    - **Primary aldosteronism**
        - Identification of primary aldosteronism
            - ☐ Serum potassium < 3.5 mEq/L and diastolic hypertension suggest aldosteronism
            - ☐ Other laboratory data: Plasma renin and 24-hour urine collection for sodium, cortisol, aldosterone
            - ☐ Most frequent form of secondary hypertension
        - Determine surgical vs. medical management
            - ☐ Gold standard for distinguishing adenomas from bilateral adrenal hyperplasia
            - ☐ APA, bilateral adrenal hyperplasia most common subtypes
            - ☐ Bilateral adrenal hyperplasia treated medically
            - ☐ Unilateral APA, adrenalectomy may normalize BP
            - ☐ US and Japanese endocrine societies recommend AVS in all patients with 1° aldosteronism considering surgical treatment
        - AVS superior to imaging for differentiating 1° aldosteronism
            - ☐ Most accurate way of differentiating subtypes
            - ☐ Diagnosing APA requires demonstration of lateralization of aldosterone hypersecretion
    - **Cushing syndrome**
        - AVS used to confirm adrenal gland as source of excess cortisol in patient with adrenal mass on imaging
        - Localization of cause of Cushing syndrome extremely important in directing therapy
            - ☐ In endogenous Cushing syndrome, urinary cortisol excretion elevated; plasma levels fail to drop in response to dose of dexamethasone
            - ☐ Pituitary or ectopic sources generally have elevated serum ACTH levels
            - ☐ With independently functioning adrenal masses, serum ACTH may be low, necessitating AVS to localize
            - ☐ Resection of functioning unilateral adrenal mass
    - **Pheochromocytomas and paragangliomas**
        - With advances in MR and CT, AVS infrequently needed
            - ☐ Used in localizing occult pheochromocytoma when imaging is equivocal or negative
            - ☐ Detection of bilateral tumors in familial syndromes, such as von Hippel-Lindau, when imaging shows only unilateral disease
- **RVS**
    - **Renovascular hypertension**
        - Determination if renal artery stenosis (RAS) is etiology of hypertension
        - Positive stimulated renal venous renin lateralization ration may be independent predictor of BP improvement following treatment of RAS
        - RVRS in evaluation/treatment of renovascular hypertension has decreased, now infrequently performed
    - **Reninoma**
        - Diagnosis and lateralization of small lesions

    - Rare renin-producing renal tumor, visible with CT/MR
    - Younger (< 25 years), females with severe hypertension, hypokalemia
- **Renal venography for diagnosis &/or treatment**
  - **NCS**
    - LRV hypertension due to compression between superior mesenteric artery/abdominal aorta
      - ☐ Uncommon causes: Pancreatic/retroperitoneal neoplasm, AAA, left renal ptosis, pregnancy
    - May produce chronic left flank/pelvic pain, hematuria, orthostatic proteinuria, and vague gastrointestinal symptoms
    - May result in male varicoceles, female pelvic congestion syndrome
    - Has been treated with LRV stent with varying degrees of success
    - May resolve spontaneously without treatment (e.g., thin patients who increase body mass index, children as they grow)
  - **Pelvic congestion syndrome**
    - Left ovarian vein drains into LRV
    - Left renal venography may demonstrate reflux into dilated ovarian vein, indicating venous valvular incompetency
  - **Varicocele**
    - Left internal spermatic (gonadal) vein drains directly into LRV
    - Left renal venogram may show reflux into gonadal vein; diagnosis of venous valvular incompetency

Contraindications

- AVS contraindications
  - Adrenalectomy surgery not possible due to multiple comorbidities
  - Patient prefers lifelong medical treatment
  - Surgery mandated despite AVS outcome due to suspected adrenocortical carcinoma
  - Patients with familial hyperaldosteronism type I and type III genetic mutations
- Contrast allergy
- Renal dysfunction

Preprocedure Imaging

- CECT, thin axial sections, venous phase, useful for displaying right adrenal vein anatomy
  - May aid in directing successful catheterization, evaluate potential of right adrenal vein drainage into accessory hepatic vein

Special Considerations

- Optimizing AVS
  - Optimizing medications begins 6 weeks prior to procedure
  - Hypokalemia should be corrected prior to AVS, it decreased aldosterone secretion
  - Patient should be kept supine for 1 hour prior to AVS
  - Minimize patient's procedure-related pain and emotional stress, which can affect aldosterone secretion and obscure lateralization
  - No conclusive evidence to support cosyntropin stimulation vs. unstimulated AVS
  - If cosyntropin is not used, perform AVS in morning to avoid diurnal fluctuation of adrenocorticotropic hormone
  - If cosyntropin is not used and adrenal venous anatomy challenging, consider bilateral simultaneous catheter engagement and sampling of adrenal veins to reduce time-related variability of hormone concentrations
  - Adjust antihypertensive medications prior to AVS, utilizing α-adrenergic receptor blockers and nondihydropyridine calcium-channel blockers (verapamil), which do not affect renin release
  - Ensure direct renin < 25 mU/L; plasma renin activity < 0.60 ng/mL per hour
- Optimizing RVS
  - Optimizing medications begins 4 weeks prior to procedure
  - Strict adherence to procedural steps necessary
  - Patient maintains < 40 mmol/day sodium diet x 4 days prior to procedure
  - Verify restrictive sodium diet with 24-hour urine sample on last day
  - Patient kept recumbent from midnight before procedure

Getting Started

- Things to check
  - **AVS**
    - Ensure no mineralocorticoid receptor blockers (spironolactone) taken for 6 weeks prior to AVS
  - **RVRS**
    - Discontinue antihypertensive β blockers, ACE inhibitors, diuretics 4 weeks prior to sampling
- Medications
  - **AVS**: Proposed protocols for stimulation; cosyntropin (Cortrosyn), synthetic subunit of ACTH
    - 50 mcg/hour, starting 30 minutes prior to sampling
    - 0.25-mg bolus followed by infusion of 0.15-0.20 mg/hr, started 15 minutes prior to sampling
    - 250-mcg bolus during AVS procedure
  - **RVRS**: Proposed protocols for stimulation of renin
    - 25-mg oral captopril
    - 0.04 mg/kg (max 2.5 mg) IV enalaprilat
    - Captopril (1 mg/kg body weight) 60-90 minutes before sampling
- Angiographic sheaths and catheters
  - Vascular sheath (5-7 Fr) for femoral vein access
  - Angiographic catheters
    - Selective catheters should have sidehole near tip
    - Simmons, SOS, or Mikaelsson catheters are typical choices for right adrenal vein
    - VAN catheter (Boston Scientific) has Simmons-1 shape, plus lateral perforations near tip
    - Cobra, Simmons catheters typical choices for left adrenal vein and for either renal vein
- Iodinated contrast medium
- Laboratory vials for sample collection
- Consent: Adrenal/renal vein dissection, thrombosis; periadrenal hematoma; confounding results

PROCEDURE

Procedure Steps

- **Procedure-specific goals**
- **Adrenal venography and sampling**
  - Obtain venous access from common femoral vein puncture; introduce 6- or 7-Fr vascular sheath
  - **Primary aldosteronism**
    - Typically cannulate/sample right followed by left adrenal vein, plus peripheral vein
    - Peripheral venous sample: Obtain from access sheath or infrarenal IVC
    - Submit samples for aldosterone and cortisol assays
      - Appropriate cortisol level confirms correct catheter position within adrenal vein
    - Consider stimulating with cosyntropin, institution-specific protocol
  - **Cushing syndrome**
    - Typically cannulate/sample right followed by left adrenal vein, plus IVC above adrenal glands, and IVC below renal veins
    - Cosyntropin stimulation is not necessary
    - Submit samples for cortisol assays
  - **Pheochromocytoma**: Potential pheochromocytoma may require sampling for metanephrines and normetanephrines
  - Cannulating and sampling adrenal veins
    - Right adrenal vein
      - Right adrenal vein is short (1-15 mm) and located superior and posterior to renal vein
      - Use reverse-curve catheter (SIM 1, VAN) to selectively catheterize right adrenal vein
      - Adrenal vein typically arrayed in classic Δ form
      - Superficial spider-like veins can be present
      - Distinguish adrenal vein vs. accessory hepatic vein
      - If adrenal vein drains into accessory hepatic vein, catheter tip should be advanced through hepatic accessory vein into adrenal vein
    - Left adrenal vein
      - Use Cobra 2 or Simmons 1 or 2 catheter to cannulate left adrenal vein; may require coaxial microcatheter
      - Position catheter tip beyond left inferior phrenic vein confluence but before adrenal tributaries
    - Adrenal vein characteristics
      - Triangle-/Δ-shaped angiographic blush
      - Central vein communicating with smaller veins in stellate/spiculated pattern
      - Communicating retroperitoneal collaterals
    - Confirm catheter position, gently inject 1- to 3-cc contrast
      - Patient may experience back pain during contrast injection into adrenal vein, particularly on right
    - Aspirate from adrenal glands
      - Slow, intermittent aspiration
      - Ideally obtain 5- to 8-cc samples (discuss with laboratory at your institution)
      - If aspirate flows readily, catheter likely disengaged from adrenal vein
      - Punching small hole into catheter tip helps prevent vein collapse as sample is aspirated
      - Record time and location (right vs. left) of aspiration on each vial
- **RVS**
  - Obtain venous access from common femoral vein puncture; introduce 5-Fr vascular sheath
  - Catheterize right/left main renal vein with 5-Fr Cobra, Simmons, or VAN catheter (sidehole at tip)
    - On left, catheter should be beyond gonadal vein
  - Be certain there are no accessory/aberrant veins that also require venous sampling
  - Renin stimulation
    - Enalaprilat stimulation, obtain samples before and 20 minutes after stimulation
    - Captopril stimulation (1 mg/kg body weight) 60-90 minutes before sampling
  - Obtain 5- to 10-mL samples
    - Sample from each renal vein
    - Sample from IVC above and below renal veins
    - Sample quickly; renin levels vary with time
- **Renal venography for diagnosis &/or treatment**
  - Obtain venous access from common femoral vein puncture; introduce 5-Fr vascular sheath
  - Catheterize left main renal vein with 5-Fr Cobra, Simmons, or VAN catheter (sidehole at tip)
  - Obtain pressure measurements as catheter is withdrawn from renal hilum to IVC
  - Perform left renal venogram
    - Measure potential extrinsic compression/stenosis of LRV
    - Evaluate presence of collateral veins
    - Note any reversal of flow through left gonadal vein
  - LRV endovascular stenting
    - Consider conservative approach for 6 months prior to stenting of adults/elderly
    - Consider conservative management and surveillance in patients < 18 years old
      - Higher likelihood of spontaneous remission
      - Monitor for > 2 years unless symptoms intolerable
    - If LRV endovascular stent placement indicated
      - Noncovered stent with high radial force
      - Conformable stent which accommodates shape of vessel
      - Shortens little in length as deployed

Alternative Procedures/Therapies

- Radiologic
  - AVS augmentation by multiplanar C-arm CT imaging during 180° C-arm rotation
    - Whenever C-arm CT images shows sampling catheter in wrong position, catheter repositioned
  - Do imaging/other tests obviate need for sampling
    - Multiple studies found CT and MR have poor accuracy localizing aldosterone-producing microadenomas
    - In one study of venous sampling after equivocal CT, 22% would have had incorrect exclusion from surgery and 25% unnecessary adrenalectomy if sampling had not been done
    - New studies suggest 11C-metomidate PET-CT offers noninvasive lateralization of APA
      - Patients prefer 11C-metomidate PET-CT vs. AVS

        - ☐ 20 minute half-life of 11C-isotopes mandate on-site cyclotron
    - CT/MR can often detect reninoma
- Surgical
    - Nutcracker treatments include nephropexy, renal vein bypass, LRV transposition, SMA transposition

POST PROCEDURE

Things to Do

- **AVS**
    - When obtaining venous samples, note time obtained and label all tubes with attention to right vs. left
    - Collect samples in appropriate containers for laboratory analysis; conform to lab requirements for accurate sample analysis (e.g., refrigerated sample)
    - Adhere to strict preprocedure/procedure protocol
- **NCS**
    - Consider clopidogrel x 30 days and aspirin x 3 months after stent placement

Things to Avoid

- Adrenal veins are small, weak, and prone to rupture; avoid forceful contrast injections
- Usually tenuous selective catheter positions in adrenal veins; avoid excessive catheter movement when obtaining samples to prevent dislodgement

Interpreting Results

- **AVS**
    - Plasma cortisol concentration (PCC), plasma aldosterone concentration (PAC)
    - Selectivity index (SI)
        - PCC (side)/PCC (IVC)
        - Suggest SI cutoff > 2.0 for unstimulated AVS
        - Suggest SI cutoff > 3.0 for cosyntropin stimulated AVS
        - Values > cutoff suggests catheter position was within adrenal veins
    - Lateralization index (LI)
        - PAC (dominant)/PCC (dominant): PAC (nondominant)/PCC (nondominant)
        - Suggest LI cutoff > 2.0 for unstimulated AVS
        - Suggest LI cutoff > 4.0 for cosyntropin stimulated AVS
        - Value g > cutoff suggests lateralization present in AVS
        - LI cannot be calculated for cases that were not bilaterally selected
    - Sampling may distinguish between functioning adrenal adenoma and idiopathic adrenal hyperplasia
        - Adrenal adenoma has high aldosterone:cortisol ratio before/after ACTH; lateralizes to affected side
        - Lateralization generally considered > 4:1 ratio difference between glands
        - In bilateral hyperplasia, no lateralization of ratios before or after ACTH, but aldosterone:cortisol ratio is higher than in IVC
- **RVRS**
    - Renin levels from kidney that are > 1.5x that of contralateral kidney is positive result
        - One study suggests 1.72 as better RVRR
    - Rise in renin from infrarenal to suprarenal IVC is further evidence for renovascular hypertension
- **LRV compression**
    - Pressure gradient between LRV and IVC > 3 mm Hg
    - Presence of collateral veins
    - Ultrasound duplex peak systolic velocity of LRV central to renal-hilar > 4.2-5.0
    - CT diameter of LRV central to renal-hilar < 50%

OUTCOMES

Problems

- Most common difficulty is failure to cannulate right adrenal vein, due to challenging anatomy
- Selective catheterization of hepatic caudate lobe venous drainage often mistaken for right adrenal vein

Complications

- Most feared complication(s)
    - Adrenal vein dissection/rupture (0.5%), adrenal hemorrhage or infarction (0.5%)
- Other complications
    - Contrast reaction or contrast-induced nephropathy
    - Access site hematoma, venous thrombosis, infection
    - 0.2-13.0% overall complication rates
    - LRV endovascular stent occlusion related to fibromuscular hyperplasia
    - LRV endovascular stent migration to IVC and RA has been reported, likely due to stent undersizing

Expected Outcomes

- **AVS**
    - Most accurate means of diagnosing cause of hyperaldosteronism
    - More restrictive (higher) SI cutoff value results in increased confidence of results, but fewer AVS studies being defined as successfully bilaterally selective
    - More restrictive (higher) LI cutoff value results in population selection with higher chance of responding favorably to adrenalectomy, while excluding some of potentially curable population
- **RVS**
    - Positive stimulated RVRR may be predictor of BP response to RAS angioplasty
    - Other studies evaluating angioplasty of RAS found no benefits beyond medical treatment; however, treatments were not limited to patients with positive stimulated RVRR
- **NCS**
    - Cohort of 61 patients followed for 64 months had 97% symptomatic improvement following stenting of patients meeting criteria for LRV entrapment syndrome
    - No longer term follow-up is currently available

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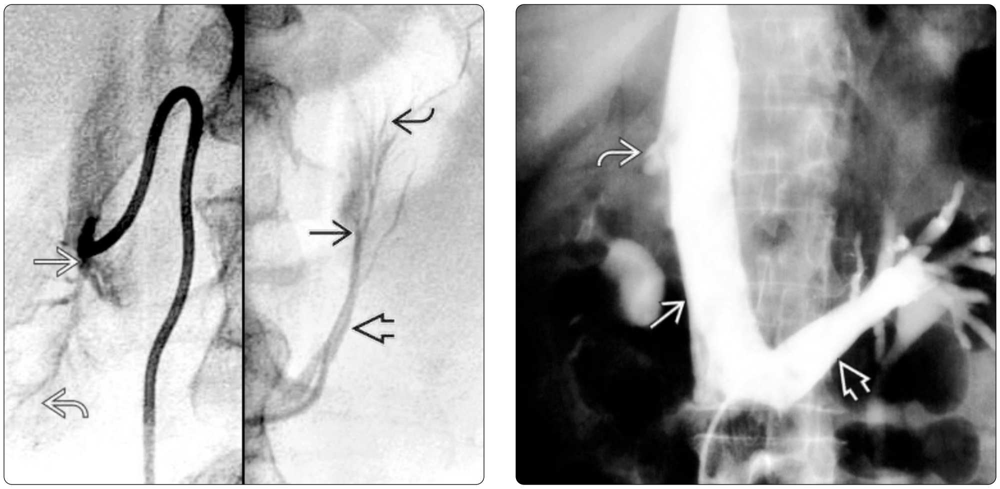
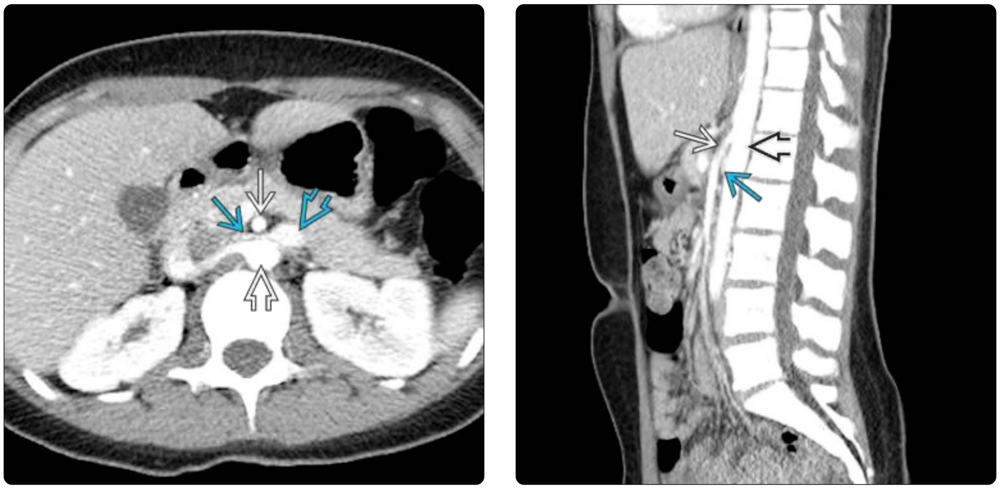


Adrenal Vein Sampling (Magnified Appearance)

Retroaortic Left Renal Venogram

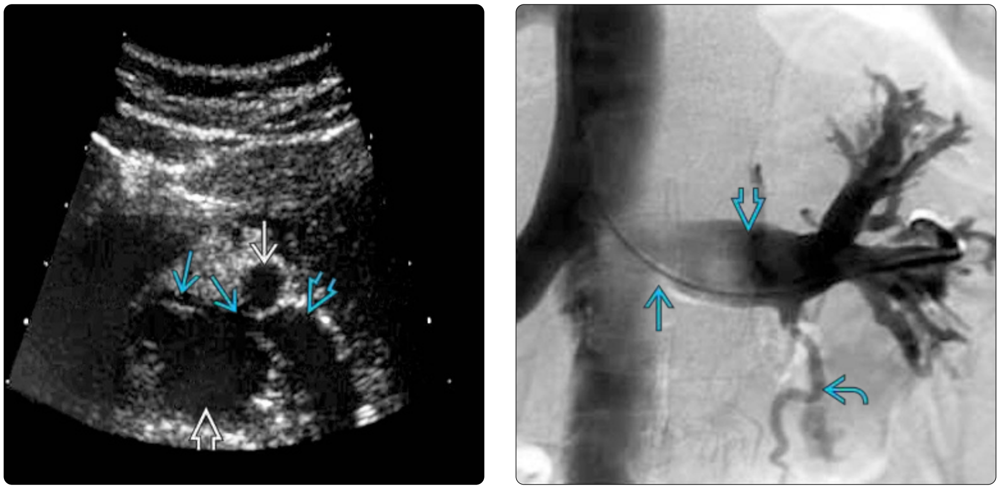
(Left) *5-French catheter venography defines the right adrenal vein main venous trunk → and tributaries ↪. Adrenal venography through a microcatheter ⇨ shows the left adrenal vein main trunk → and tributaries ↪.* **(Right)** *Venogram shows an unusual inferior course of the LRV ⇨ as it joins the IVC →. This appearance is typical of a retroaortic LRV, which is a well-known anatomic variant. A small portion of the right renal vein ↪ is seen entering the IVC at the expected location.*



Left Renal Vein Entrapment (Axial CECT)

Left Renal Vein Entrapment (Sagittal CECT)

(Left) *Axial CECT in a patient with left flank pain shows narrowing of the LRV → as it crosses between the SMA → and aorta ⇨. The LRV is dilated proximal to the narrowing ⇨.* **(Right)** *Sagittal CECT shows the extent of LRV → narrowing as it is externally compressed between the SMA → and aorta ⇨. (Courtesy K. Quencer, MD.)*



Left Renal Vein Entrapment (Axial Ultrasound)

Left Renal Vein Entrapment (Diagnostic Venogram)

(Left) *Axial grayscale ultrasound shows narrowing of the LRV → as it courses between the SMA → and aorta ⇨. Dilation of the LRV ⇨ is present between the kidney and the compressed segment of vein.* **(Right)** *A left renal venogram confirms LRV narrowing → as it crosses between the SMA and aorta. Dilation of the proximal LRV ⇨ and left gonadal vein ↪ is present. (Courtesy J. J. Borsa, MD.)*

Venous Sampling and Venography: Endocrine, Nonadrenal

KEY FACTS

TERMINOLOGY

- **Inferior petrosal sinus sampling (IPSS)**
  - Evaluates for adrenocorticotrophic hormone (ACTH)-secreting pituitary adenoma as etiology for endogenous Cushing syndrome
- **Pancreatic endocrine tumors: Arterial stimulation and selective venous sampling (ASVS)**
  - Used for pancreatic endocrine tumor localization
- **1° hyperparathyroidism: Selective venous sampling (SVS)**
  - Negative/inconclusive imaging and prior noncurative surgery for 1° hyperparathyroidism

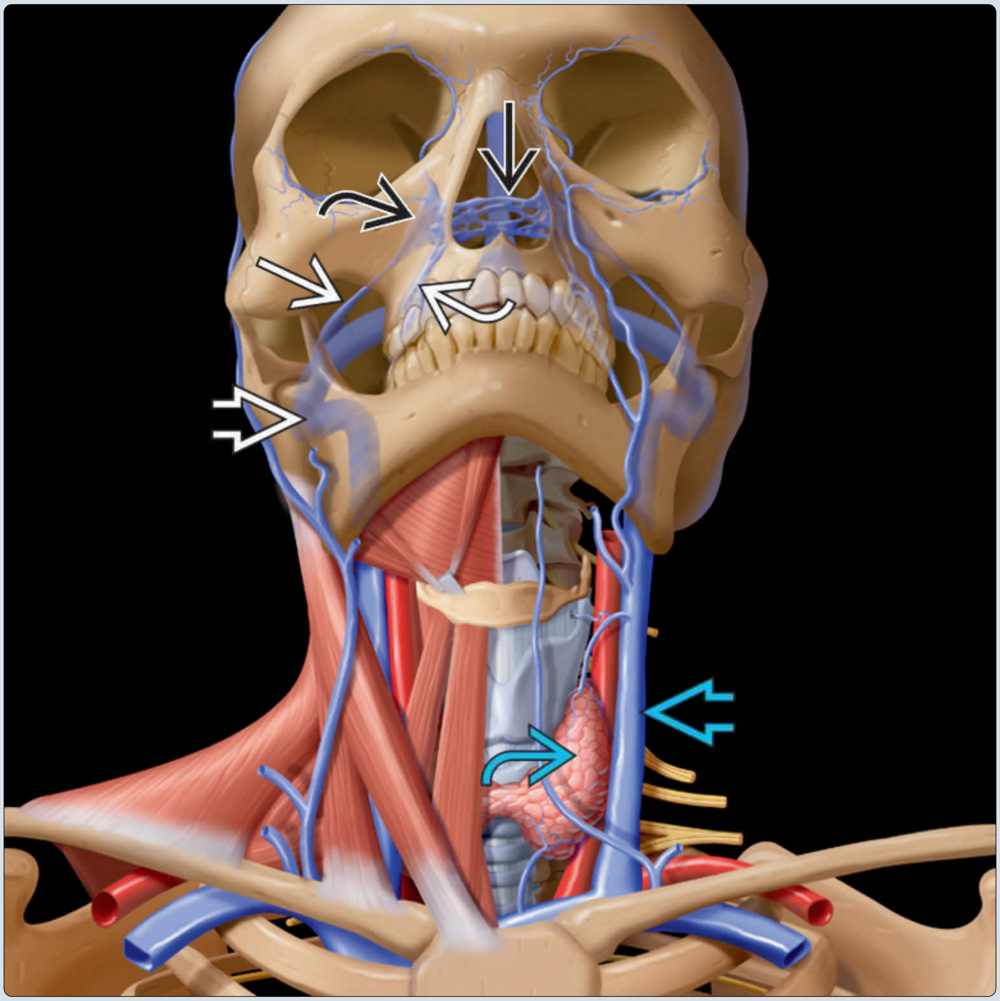
PREPROCEDURE

- IPSS improves diagnostic accuracy in distinguishing pituitary vs. ectopic source of ACTH
- Parathyroid SVS has > 90% sensitivity for localizing ectopic glands/prior unsuccessful surgery

PROCEDURE

- For IPSS, obtain baseline peripheral, simultaneous inferior petrosal sinus venous samples
  - Inject 100 μg of corticotrophin-releasing hormone
  - Obtain inferior petrosal sinus and peripheral blood samples 3, 5, 10, 15 minutes afterward
  - Basal central:peripheral ACTH ratio > 2, stimulated interpetrosal sinus ratio > 1.4 localizes tumor
- For ASVS, calcium secretogogue causes rise in hepatic vein insulin or gastrin level (> 50% is positive)
  - Tumor site predicted by arterial injection locale
- For SVS for hyperparathyroidism, obtain blood samples from neck/mediastinal veins; multiple levels
  - Positive sample is 1.5x increase over peripheral parathyroid hormone (PTH) measurement; reported by catheter position

Pituitary and Parathyroid Venous Drainage



The pituitary venous plexus ⇨ drains into the cavernous sinuses ↷. These drain via the superior ➡ and inferior ➥ petrosal sinuses into the sigmoid sinuses ➡ and the internal jugular veins ⇨. The normal location of the parathyroid glands is on the posterior aspect of the thyroid gland ↷. The thyroid and parathyroid glands drain into both internal jugular and brachiocephalic veins.

TERMINOLOGY

Definitions

- **Inferior petrosal sinus sampling (IPSS)**: Venous blood sampling from both inferior petrosal sinuses
    - Evaluates for adrenocorticotrophic hormone (ACTH)-secreting pituitary adenoma as etiology for endogenous Cushing syndrome
    - Considered gold standard for confirming origin of ACTH secretion in Cushing syndrome
- **Pancreatic endocrine tumors: Arterial stimulation and selective venous sampling (ASVS)**
    - Used for preoperative localization of pancreatic endocrine tumors
        - Evaluates for gastrinoma, insulinoma, VIPoma, glucagonoma, somatostatinoma, pancreatic polypeptide-producing tumor (PPoma)
- **1° hyperparathyroidism: Selective venous sampling (SVS)**: Sampling from veins draining parathyroid gland for parathyroid hormone (PTH) assay
    - Preoperative localization of functioning parathyroid adenoma that cannot be localized by imaging
        - Negative/inconclusive imaging findings; prior noncurative surgery for 1° hyperparathyroidism

PREPROCEDURE

Indications

- **IPSS**
    - Cushing syndrome: Clinical complex caused by prolonged inappropriate glucocorticoid exposure
        - Most frequently caused by administration of exogenous glucocorticoids or ACTH
        - Endogenous causes include ACTH-secreting pituitary tumor, adrenal neoplasm (benign or malignant), or ectopic ACTH secretion by tumor
            - ☐ Pituitary or ectopic sources generally have elevated serum ACTH levels
            - ☐ In endogenous Cushing syndrome, urinary cortisol excretion elevated; plasma levels fail to drop in response to dose of dexamethasone
        - 40-50% of pituitary Cushing disease patients have no pituitary lesion on MR; also, demonstrating lesion does not imply functionality
            - ☐ 10% of population aged 30-40 harbor incidental pituitary abnormality
            - ☐ IPSS improves diagnostic accuracy distinguishing pituitary vs. ectopic ACTH source
- **Pancreatic endocrine tumors: Preoperative localization**
    - Insulinoma accounts for 50-60%
        - Symptoms: Hypoglycemia, palpitations, diplopia; elevated serum insulin and C-peptide levels
        - 75% solitary and benign; 10% malignant
    - Gastrinoma (20% incidence)
        - Causes Zollinger-Ellison syndrome: Severe peptic ulcer disease, gastric hypersecretion, elevated serum gastrin, diarrhea, and non-B islet cell tumor
        - 40% of gastrinomas are intrapancreatic, 60% extrapancreatic; often multiple
            - ☐ Duodenum frequent extrapancreatic site (40%)
        - Hypervascular but less so than insulinoma
- **1° hyperparathyroidism**
    - Estimated prevalence of 1:1,000
        - Corrected calcium > 2.65 mmol/L on 2 occasions
        - Inappropriately high or normal PTH level
        - Urine fractional calcium excretion ratio > 0.01
    - 85% of cases secondary to parathyroid adenoma
        - Superior parathyroid glands usually located posterolateral to superior pole of thyroid gland
        - Inferior glands develop and descend with thymus
        - 10% of parathyroid adenomas may be in ectopic location; 5-10% of parathyroid glands ectopic
            - ☐ Ectopic locations: Anterior mediastinum (10%), posterior mediastinum (3-5%), within thyroid gland (1-3%), and retroesophageal (1%)
    - Increased failure/complication rates of repeat parathyroid surgery compared with initial operations
        - Due to postoperative scarring
    - Preoperative localization studies used before repeat surgery for persistent hyperparathyroidism
        - Can reduce complexity of repeat surgical dissection and complication rate
        - Localization imaging includes ultrasound, scintigraphy (Tc-99m sestamibi), CT, MR
        - Invasive procedure of SVS also used for localization
        - SVS frequently indispensable when imaging negative/inconclusive and prior neck surgery

Getting Started

- Medications
    - IPSS: 100 mg of corticotrophin-releasing hormone (CRH)
    - ASVS: 5 mL of calcium gluconate (0.025 mEq Ca^{++}/kg)
        - Used for localizing insulinoma/gastrinoma
            - ☐ Can use secretin 30 IU/5 mL NS for gastrinoma

PROCEDURE

Procedure Steps

- **IPSS**
    - Obtain common femoral vein access, introduce 2 separate vascular sheaths
    - Introduce separate selective catheters into right and left internal jugular (IJ) veins
        - Easier to catheterize left IJ from right femoral access
    - Administer intravenous heparin
        - Typically 5,000 unit bolus
        - Prevention of sinus thrombosis/stroke
    - Advance microcatheter through each IJ catheter
        - Selectively position microcatheters into right and left inferior petrosal sinuses
        - Confirm catheter position with contrast injection
    - Obtain simultaneous venous samples from microcatheters and peripheral sheath for baseline
    - Inject 100 mg IV of stimulating agent, CRH
        - Obtain inferior petrosal sinus and peripheral blood samples 3, 5, 10, 15 minutes after IV CRH
    - Label tubes with time, sample location, right vs. left
    - Submit samples for laboratory assays
- **Pancreatic endocrine tumors: ASVS**
    - Obtain common femoral arterial access
        - Place vascular access sheath
    - Obtain IJ or femoral venous access

      - Place vascular access sheath
  - Selectively catheterize right or middle hepatic vein
  - Selectively catheterize SMA, hepatic, gastroduodenal, splenic, pancreatic branch arteries
    - Perform selective angiography at each arterial site
      - Obtain baseline 5 mL of hepatic vein blood sample
      - After each selective arteriogram inject secretagogue via arterial catheter
      - Obtain hepatic vein samples 20, 40, 60 seconds after injection; some sample up to 3 minutes
    - Allow 5 minutes between each stimulation; repeat in each arterial site
  - Keep samples on ice until delivered to laboratory
- **1° hyperparathyroidism: SVS**
  - Obtain venous access from common femoral vein puncture, with introduction of vascular sheath
    - Use guiding catheter to access neck/mediastinal veins
      - Coaxial microcatheter to sample smaller veins
  - Obtain baseline sample from peripheral sheath
  - Obtain blood samples from neck/mediastinal veins
    - Both IJ veins (distal, mid, proximal)
    - Both subclavian veins (distal and proximal)
    - Both brachiocephalic veins (distal and proximal)
    - Middle and superior thyroidal veins
    - Right and left inferior thyroidal veins
      - Normal venous drainage pathway of superior/inferior parathyroid glands
    - Thymic vein
    - Internal mammary veins
    - SVC
  - Accurately mark samples by exact location; prepare per laboratory requirements (e.g., tube type, on ice)

Alternative Procedures/Therapies

- Radiologic
  - **Parathyroid venous sampling alternatives**
    - Parathyroid ultrasound can localize/distinguish enlarged glands
      - Operator dependent
      - Less sensitive for ectopic locations
    - Tc-99m sestamibi parathyroid scintigraphy uses radioisotope accumulation within thyroid and parathyroid tissue for localizing glands
    - Radioisotope clears more quickly from thyroid than from parathyroid tissue, enabling localization
    - Combined ultrasound and Tc-99m sestamibi have greater sensitivity than as independent modalities
    - CECT and MR useful for ectopic gland detection
  - **Pancreatic endocrine tumors: ASVS alternatives**
    - CECT with imaging in arterial and venous phases
    - MR with fast spin-echo fat-saturation sequences and dynamic contrast-enhanced imaging
      - More sensitive than CECT
    - Endoscopic ultrasound can precisely localize small lesions but less sensitive in pancreatic tail
      - High false-positive rate
    - Somatostatin-receptor scintigraphy (In-111 pentetreotide); less sensitive for insulinoma
    - Transhepatic portal venous sampling has 0.7% mortality and 9.2% morbidity
      - Has been abandoned in favor of ASVS
- Surgical
  - **IPSS**, in ACTH-dependent Cushing disease and pituitary macroadenoma
    - Surgery without sampling

POST PROCEDURE

Interpreting Results

- **IPSS**
  - Basal ratio of central to peripheral ACTH; ratio > 2 considered positive
  - Because ACTH secretion is episodic, CSH stimulation used to increase sensitivity; peak stimulated ratio > 3 strongly indicative of Cushing disease
  - Interpetrosal sinus ratio > 1.4 indicative of ipsilateral localization of pituitary microadenoma
- **Pancreatic endocrine tumors: ASVS**
  - Calcium secretogogue will cause rise in insulin or gastrin level in hepatic vein (> 50% is positive)
  - Reported by which arterial injection site causes hormonal rise; predicts tumor site within pancreas
- **Primary hyperparathyroidism: SVS**
  - Positive sample is 1.5x increase over peripheral PTH measurement; reported by catheter position

Things to Do

- When obtaining venous samples, note time obtained; label all tubes with attention to right vs. left
- Collect samples in appropriate containers for laboratory analysis; conform to lab requirements for accurate sample analysis (e.g., refrigerated sample)

Things to Avoid

- False-negative ASVS results in patients on diazoxide; stop medication prior to ASVS

OUTCOMES

Complications

- Complications of IPSS include
  - Brainstem stroke, subarachnoid hemorrhage, cavernous sinus thrombosis, cranial nerve palsies
- Complications of pancreatic ASVS include
  - Hypoglycemia from systemic release of insulin during calcium stimulation, hypercalcemia from injection of calcium gluconate (both rare)

Expected Outcomes

- Sensitivity of IPSS with CRH stimulation (88-97%)
- Sensitivity of ASVS: Gastrinoma (77%), insulinoma (92%)
  - Sensitivity of angiography alone: Gastrinoma (20-86%) (location dependent), insulinoma (35-94%)
- Parathyroid SVS has very high sensitivity for localizing ectopic glands/prior unsuccessful surgery (> 90%)

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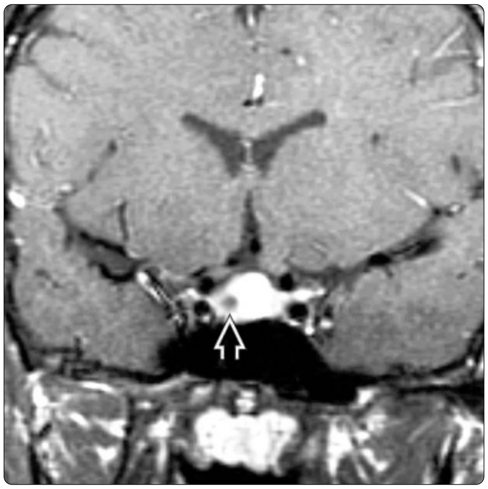
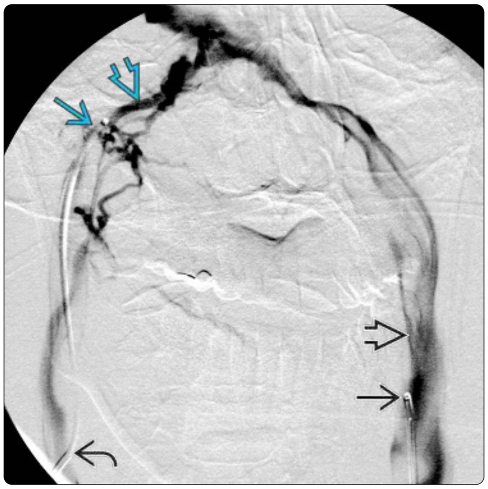
Inferior Petrosal Sinus Sampling (Coronal MR With Gadolinium)

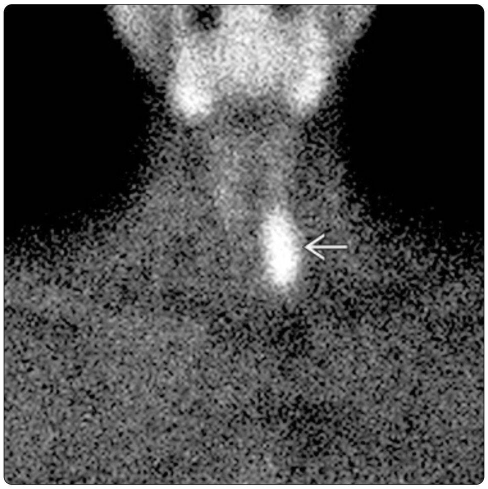


Inferior Petrosal Sinus Sampling (Venography)

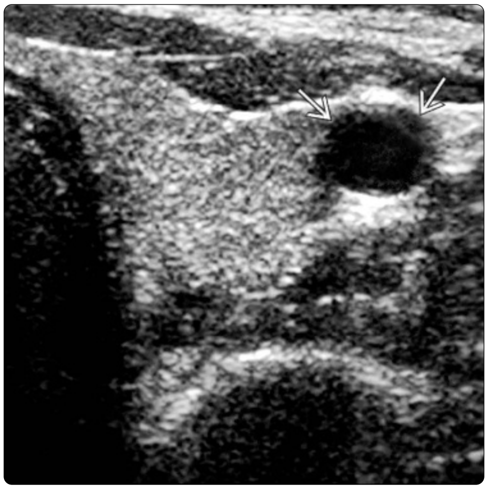


(Left) *A right-sided nonenhancing focus* ➡ *in the pituitary gland is suspicious for a microadenoma in this patient with elevated serum ACTH levels.* **(Right)** *Subsequently, a guiding catheter* ⇨ *is advanced into the right internal jugular vein, with a coaxial microcatheter* ⇨ *in the right inferior petrosal sinus* ⇨. *The contralateral catheter* ⇨ *is in the left internal jugular vein* ⇨, *and a microcatheter will be advanced into the inferior petrosal sinus for simultaneous venous sampling.*

Primary Hyperparathyroidism (Tc-99m Sestamibi Radionuclide Scan)

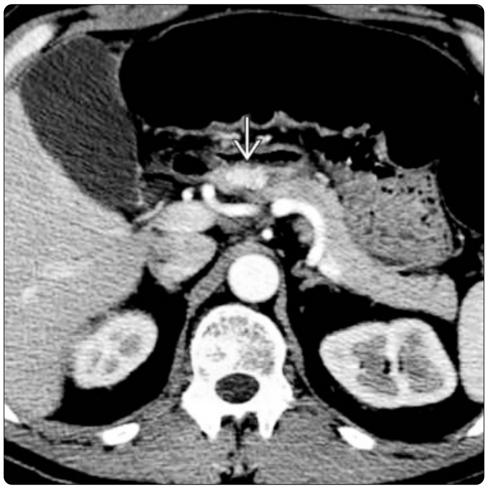


Primary Hyperparathyroidism (Ultrasound)

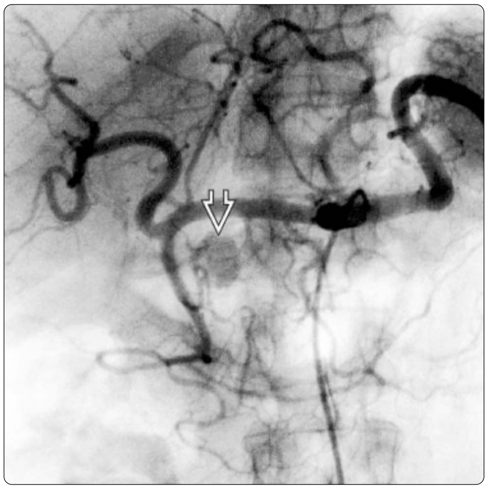


(Left) *Radioisotope accumulation* ➡ *is seen over the left lower lobe of the thyroid gland suspicious for a functioning parathyroid adenoma in this patient with primary hyperparathyroidism.* **(Right)** *A hypoechoic nodule* ➡ *in the left lower lobe of the thyroid gland corresponds to the radionuclide scan accumulation, confirming the suspected parathyroid adenoma. Selective venous sampling may be necessary in patients with negative or inconclusive imaging or prior noncurative neck surgery.*

Insulinoma (CECT)



Insulinoma (Celiac Angiogram)



(Left) *An enhancing area* ➡ *is seen in the pancreatic head in a patient with severe hypoglycemia, tachycardia, and diplopia. Laboratory tests showed elevated serum insulin and C-peptide levels.* **(Right)** *An enhancing mass* ➡ *corresponds to the CT abnormality. When stimulation and venous sampling are necessary, calcium gluconate is selectively injected intraarterially, and hepatic venous samples are obtained.*

Ambulatory Phlebectomy and Sclerotherapy

KEY FACTS

TERMINOLOGY

- **Phlebectomy**: Mechanical avulsion of diseased, superficial varicose vein segments using small hooks through multiple stab incisions
- **Sclerotherapy**: Percutaneous injection of sclerosant (medication) to thrombose diseased, superficial varicose vein segments
- **Superficial veins**: Innumerable venous tributaries known as collecting veins, great saphenous vein (GSV), small saphenous vein (SSV)

PREPROCEDURE

- Treatment of proximal to distal superficial venous insufficiency critical for good outcomes
- After proper clinical evaluation, must first treat any GSV/SSV reflux with endovenous thermal ablation &/or sclerotherapy
- May perform phlebectomy/sclerotherapy after treatment of proximal venous disease or concurrently

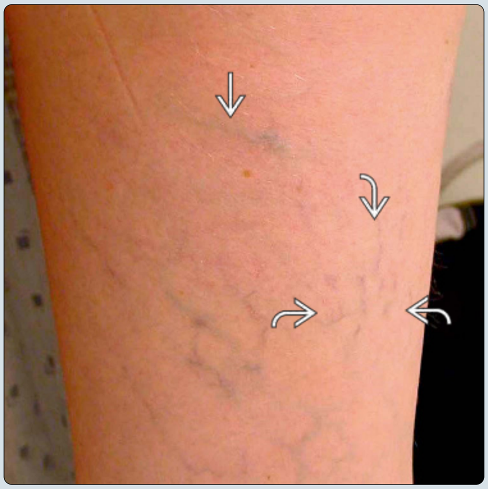
PROCEDURE

- **Ambulatory phlebectomy**
  - Make microincisions directly over target vein
  - Introduce phlebectomy hook, rotate against vein
  - Bring hooked vein through incision, gently avulse
- **Sclerotherapy**
  - Injection with liquid sclerosant should proceed from proximal leg veins and progress distally
  - Reverse pattern recommended with foam therapy

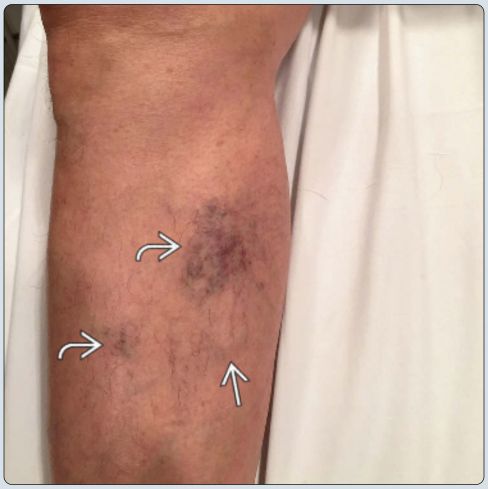
POST PROCEDURE

- Excellent symptom relief/cosmesis in most patients
- Treatment area dressing critical to follow-up care
- Class II graduated compression stocking (30-40 mm Hg) should be worn
  - Applies extra pressure, keeps dressings in place

Pretreatment (Reticular and Spider Veins)

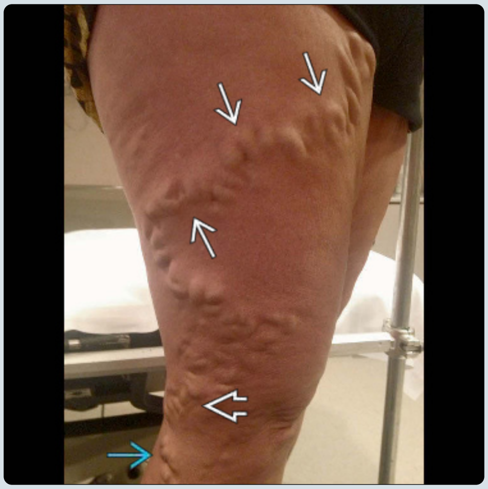


Pretreatment (Reticular Veins and Telangiectasia)

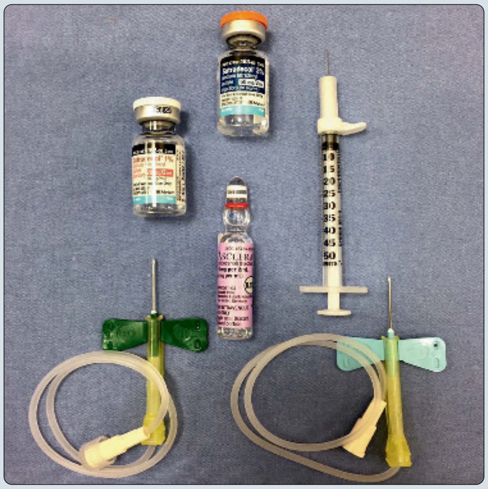


(Left) *Clinical photograph shows both reticular ➔ and spider ↷ veins involving a patient's lower leg. Sclerotherapy is an appropriate and effective treatment option for these types of varicosities.* **(Right)** *Reticular veins ➔ and areas of telangiectasia ↷ such as this are often symptomatic and appropriate for treatment with sclerotherapy.*

Pretreatment (Large Superficial Varicose Veins)



Sclerotherapy Equipment



(Left) *Clinical photograph shows large, superficial varicose veins ➔ arising from the anterior accessory saphenous and extending along the lateral thigh into the calf ⇨. Superficial varices such as these are treatable with ambulatory phlebectomy. Caution is advised when performing phlebectomy of the lateral aspect of the calf proximally → due to potential injury of the common peroneal nerve.* **(Right)** *Commonly used items for percutaneous sclerotherapy of varicose veins include sclerosing agents and small-gauge needles.*

TERMINOLOGY

Synonyms

- Ambulatory phlebectomy, microsurgical phlebectomy, office phlebectomy, stab avulsion phlebectomy, Müller phlebectomy, percutaneous miniphlebectomy

Definitions

- **Phlebectomy**: Mechanical avulsion/removal of diseased, superficial varicose vein segment(s)
  - Small hooks introduced via multiple stab incisions
  - Hooks used to avulse/remove vein segment(s)
- **Sclerotherapy**: Percutaneous injection of sclerosant to thrombose diseased, superficial varicose veins
  - Foam sclerotherapy: Sclerosant mixed with air/carbon dioxide to create injectable foam
    - Can use to ablate great saphenous vein (GSV), small saphenous vein (SSV), perforating veins
- **Superficial veins**: Lower extremity veins located superficial to fascia surrounding muscle compartments
  - Include innumerable venous tributaries known as collecting veins, GSV, SSV
- **Superficial venous insufficiency**: Usually caused by primary degenerative disease of superficial vein wall
  - Resultant valvular dysfunction
    - Leads to venous reflux/venous hypertension
- **Venous reflux**: Retrograde flow within veins in which valves fail
  - Clinically significant reflux in truncal veins lasts > 0.5-1.0 seconds following release of compression on muscular mass below vein

PREPROCEDURE

Indications

- Adjunctive therapy for varicose side branch veins in same setting of GSV/SSV ablation
- Treatment of varicose side branch veins that persist after adequate ablation of GSV/SSV
- Primary treatment for varicose side branch veins when ablation of GSV/SSV is contraindicated
  - e.g., when deep venous system compromised
- Treatment of varicose veins fed by focal source (e.g., incompetent perforator vein)
- Sclerotherapy (not phlebectomy) for telangiectasia, reticular veins

Contraindications

- Infectious dermatitis, cellulitis involving region for planned phlebectomy &/or sclerotherapy
- Bleeding diathesis or coagulopathy
  - Relative contraindication
- GSV/SSV inappropriate for ambulatory phlebectomy (too deep)
- Allergy to local anesthetics
- Inability to ambulate or wear compression stockings
- Severe peripheral edema or lymphedema
- Known right-to-left intracardiac shunt (sclerotherapy)
- Pregnancy

Getting Started

- Things to check
  - Treatment of entire proximal to distal superficial venous insufficiency critically important for good outcomes/limiting recurrence
  - After clinical evaluation, first treat GSV/SSV reflux with endovenous thermal ablation (EVTA) &/or sclerotherapy
    - May perform phlebectomy/sclerotherapy after treating proximal venous disease or concurrently
  - Ambulatory phlebectomy in ankle: Foot should be given special care to avoid neurovascular injury
- Medications
  - **Tumescent anesthesia**
    - Delivery of large volumes of diluted local anesthetic agent to create large region of anesthesia
      - ☐ Can use same mixture (0.1% lidocaine) for ambulatory phlebectomy as for EVTA
    - Amount of local anesthetic agent used should follow patient's body weight recommendations
      - ☐ Up to 5 mg of lidocaine/kg of body weight; if epinephrine added, up to 7 mg/kg of lidocaine
      - ☐ Potential advantage of epinephrine is contraction of superficial veins, decreasing amount of bleeding
      - ☐ Potential risks associated with epinephrine include skin necrosis, tachycardia
  - **Sclerosants**
    - Detergents: Disrupt vein cellular membrane via protein theft denaturation
      - ☐ Sodium tetradecyl sulfate (Sotradecol; AngioDynamics; Queensbury, NY)
      - ☐ Polidocanol (Asclera; BioForm Medical; Weisbaden, DE) (Aethoxysclerol; Teuto-Brasileiro Laboratorio; Anápolis, Goiás, Brazil)
      - ☐ Sodium morrhuate (Scleromate; Glenwood LLC; Englewood, NJ)
      - ☐ Ethanolamine oleate (Ethamolin; QOL Medical; Vero Beach, FL)
    - Osmotic agents: Damage cell by shifting water balance through cellular gradient (osmotic) dehydration and cell membrane denaturation
      - ☐ Hypertonic sodium chloride solution
      - ☐ Sodium chloride solution with dextrose (Sclerodex; Omega Labs; Mogadore, OH)
    - Chemical irritants: Damage cell wall by direct caustic destruction of endothelium
      - ☐ Chromated glycerin (Sclermo; Laboratoires E. Bouteille; Limoges, France)
      - ☐ Polyiodinated iodine
    - Hypertonic saline, sodium tetradecyl sulfate, polidocanol, chromated glycerin used most often

PROCEDURE

Procedure Steps

- **Ambulatory phlebectomy**
  - Place patient in standing position, mark veins to be treated with surgical pen or marker
  - Place patient supine on procedure table; sterilely prepare/drape treatment area
  - Can use transillumination to relocate target vein
  - Instill tumescent anesthesia around vein
    - Permits vein extraction, limits patient discomfort
  - Perform cutaneous microincisions over vein

    - Size of microincisions varies between 1-3 mm
      - Longer microincision may cause more visible scar; greater possibility of pigmentation
    - In thigh, lower leg, foot, vertical microincisions may potentially yield better cosmetic result
    - Around knee, tension lines should be followed
  - Introduce phlebectomy hook via microincision, rotate in perpendicular plane against target vein
  - After vein hooked, gently bring to skin surface through incision, grasp with mosquito clamp
  - Use gentle rotating motion and traction to loosen vein; slowly avulse from perivenous adventitial tissues
  - As vein segment becomes larger/longer with gentle traction, reposition clamp closer to skin surface
    - Decreases tensile force on vein
  - After vein is hooked, should come out easily
    - If patient experiences pain or vein removal requires excessive tension, different structures such as nerve/tendon have been hooked
      - Remove hook, reinsert for another attempt
  - Hemostasis with intra-/postprocedure local compression
- **Sclerotherapy**
  - Need excellent lighting, transillumination, or US
    - Identifies vein; provides access/injection guidance
    - Use US-guided injection for larger varicose veins; can access reticular veins/telangiectasias without
  - Use small-gauge needles
    - Insert needle bevel up
      - Depth of penetration more accurately assessed
  - Sclerosant concentration depends on sclerosant type, vessel size
    - Smaller vessels require less concentrated solutions
  - Foam sclerotherapy gives longer dwell time than liquid; extended contact time with vessel wall
    - Lower concentrations used to achieve same results
    - Foam created with 2-way or 3-way stopcock, 2 syringes (1 with room air, 1 with sclerosant)
    - Air solution mix is passed quickly between 2 syringes for rapid agitation and foam creation
    - Typical air to sclerosant ratios are 3:1 to 5:1
  - Blood return can ensure entry into larger veins
  - Injection with liquid sclerosant should proceed from proximal leg veins and progress distally
    - Reverse pattern (distal to proximal) recommended with foam therapy
  - Injection should be precise and slow
  - Each injection usually 0.1-0.4 mL
    - Use 1-mL syringe (feel resistance, control volume)
  - Perform injections at 2- to 3-cm intervals
  - Severe pain or burning often sign of extravasation
    - Inject site with normal saline solution or lidocaine
      - Dilutes sclerosant
  - Small-injection volumes, low-injection pressure minimize adverse effects, such as telangiectatic matting, ischemic ulceration, and extravasation

POST PROCEDURE

Things to Do

- Treatment area dressing critical step in follow-up care
  - Cover microincisions with Steri-Strips, sterile gauze, high-elasticity bandage
  - Class II graduated compression stocking (30-40 mm Hg) should be worn over dressing if possible
    - Applies extra pressure, keeps dressings in place
    - Alternatively, may use gauze/elastic bandage/tape "triple wrap" for 24 hours
- Remove sterile gauze 1-2 days post procedure
- Compression stocking worn for 2-3 weeks (daytime only)
- Encourage patient to ambulate immediately post procedure and as much as possible at home
- Discourage vigorous exercise or heavy lifting for 1st week
  - Avoids increased venous pressure on treated area
- Use over-the-counter medications such as ibuprofen or acetaminophen for pain control
- Have patient return for evaluation of microincisions
- Encourage sun protection use (sunblock/skin covering) for treatment areas: Decreases scar discoloration

OUTCOMES

Complications

- Most feared complication(s)
  - Transient visual disturbance after sclerotherapy
    - Postulated endothelin-mediated neurologic event
      - Similar to migraine aura; not ischemic event
    - Possible trigger: Foam entering cerebral circulation
    - Risk factors include patent foramen ovale and history of migraine headaches
    - Symptoms may last from 30 minutes to 3 hours
  - Deep venous thrombosis (infrequent)
- Immediate/periprocedural complication(s)
  - Ambulatory phlebectomy
    - Damage to small cutaneous nerves may cause paresthesias, pain, temporary foot drop
    - Hematomas, more often seen in popliteal region
    - Infection (includes phlebitis of incompletely removed segments, wound infections, cellulitis)
  - Sclerotherapy
    - Superficial thrombophlebitis
      - Treat with compression, NSAIDs
      - Evacuation of liquefied thrombus helpful
    - Allergic reactions, urticaria, possible anaphylaxis
    - Tissue necrosis (extravasation/arteriolar injection)
- Delayed complication(s)
  - Transient hyperpigmentation
    - Due to hemosiderin staining after hematoma resorption; postinflammatory melanocytes
    - Commonly fades in weeks to months
    - May not resolve completely (include in consent)

Expected Outcome

- Excellent symptom relief/cosmetic results achieved in most patients

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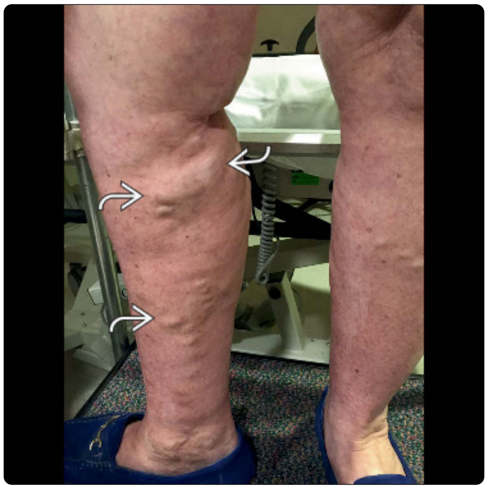
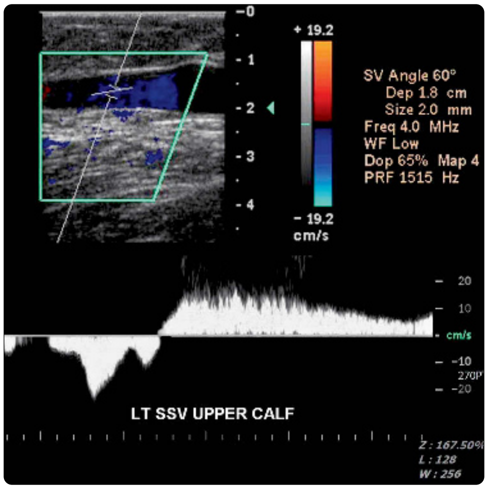
Ambulatory Phlebectomy (Pretreatment Standing Evaluation)

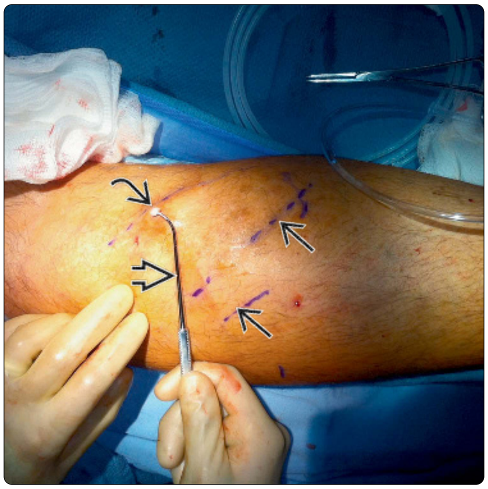


Ambulatory Phlebectomy (Ultrasound Visualization of Reflux)

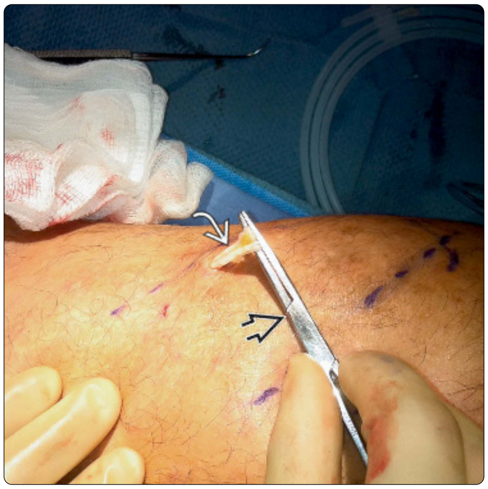


(Left) *Clinical photograph of the leg shows extensive prominent varicose veins ➦ involving the posterior calf of a patient with significant calf pain and swelling.* **(Right)** *Color Doppler US shows marked reflux in the small saphenous vein (SSV). Additional imaging showed that the large varicose veins in the posterior calf arose from the incompetent SSV. The patient initially underwent endovenous laser ablation of the SSV for elimination of the source of reflux. Elimination of the reflux is necessary prior to ambulatory phlebectomy.*

Ambulatory Phlebectomy (Varicose Vein Brought to Skin)

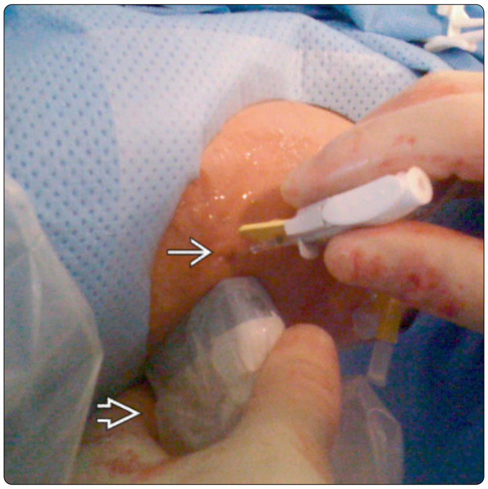


Ambulatory Phlebectomy (Avulsion of Varicose Vein)

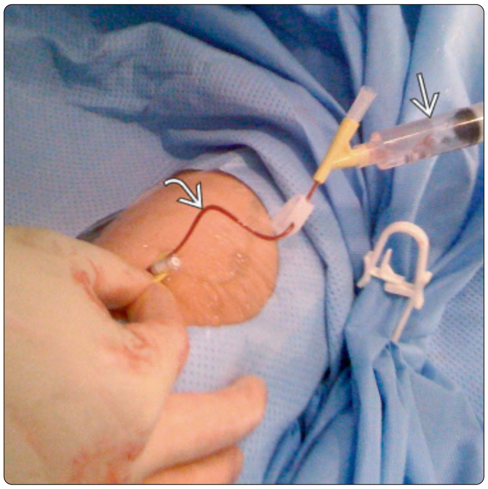


(Left) *Intraoperative photograph shows that the varicose veins have been outlined → with a marking pen. Tumescent anesthesia is instilled to ease vein extraction and limit discomfort. A microincision ↪ is made and the phlebectomy hook ⇨ is inserted. The hook is rotated against the vein, and it is brought to the skin surface through the incision.* **(Right)** *After the vein ➦ has been brought to the surface, it is grasped with a mosquito clamp ⇨, loosened, and slowly avulsed from the perivenous adventitial tissues.*

Sclerotherapy (Varicose Vein Needle Access)



Sclerotherapy (Delivery of Sclerosant)



(Left) *Intraoperative photograph obtained during sclerotherapy of varicose veins shows a needle ➡ being inserted into a target vein using ultrasound guidance ➡. Ultrasound is used to guide injection of the sclerosant into the varicosities.* **(Right)** *Intraoperative photograph shows a small-volume syringe ➡ containing the sclerosant attached to the connector tubing ➦ of the needle used for access. Under US guidance and with low pressure, a small volume is slowly administered into the target vein.*

Saphenous Vein Ablation

KEY FACTS

TERMINOLOGY

- Endovenous thermal ablation (EVTA): Procedure in which thermal energy is endovenously delivered to vein wall
  - Causes irreversible occlusion, eventual fibrosis
  - Eliminates incompetent superficial truncal veins causing superficial venous insufficiency
  - Can use laser or radiofrequency energy

PREPROCEDURE

- Indications: Symptomatic lower extremity venous insufficiency affecting quality of life
  - Pain, aching, throbbing, heaviness, fatigue, pruritus, night cramps, restlessness, swelling
  - Skin changes of chronic venous hypertension
- Thorough evaluation of venous system with duplex US
- Evaluate anatomy, physiology, patency, and reflux
  - Assess deep/superficial/perforating veins

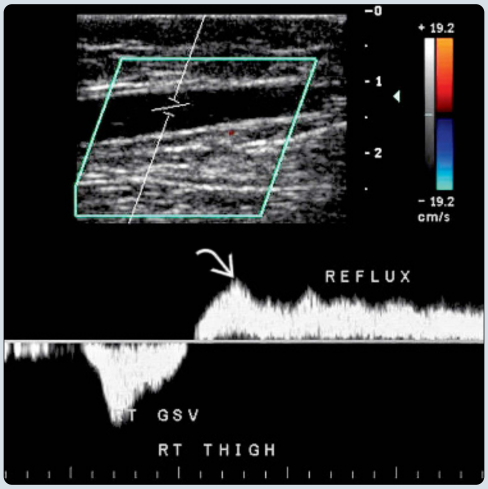
PROCEDURE

- Micropuncture access of lowest incompetent venous segment, avoiding lower 1/3 of calf
- Pass guidewire superiorly beyond saphenofemoral junction or saphenopopliteal junction
  - Place introducer sheath over guidewire
- Using US, advance ablation device via introducer sheath to most central location of vein to be treated
- With treatment catheter in place, deliver perivenous tumescent anesthesia
- Activate and slowly withdraw catheter, ensuring enough energy deposition per segment treated
  - System-dependent pullback speed/required energy

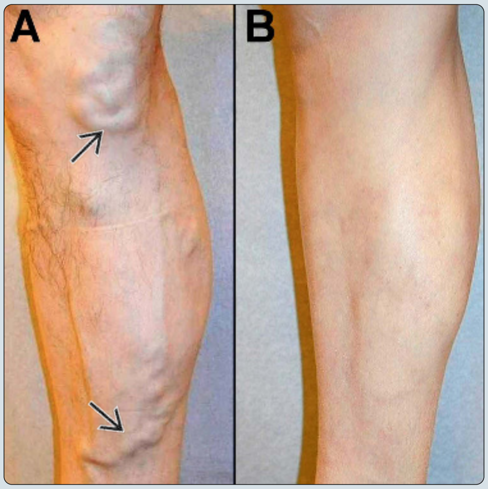
POST PROCEDURE

- Adequate compression is critical in follow-up care
  - Class II compression stockings (30-40 mm Hg) preferable if tolerated

Preprocedure Assessment (Great Saphenous Vein Reflux)

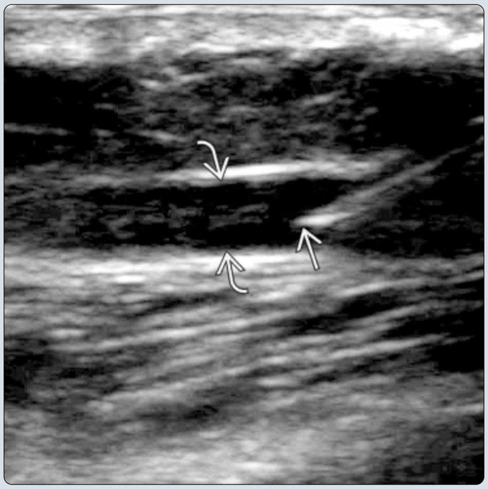


Clinical Photographs (Pre and Post Treatment)

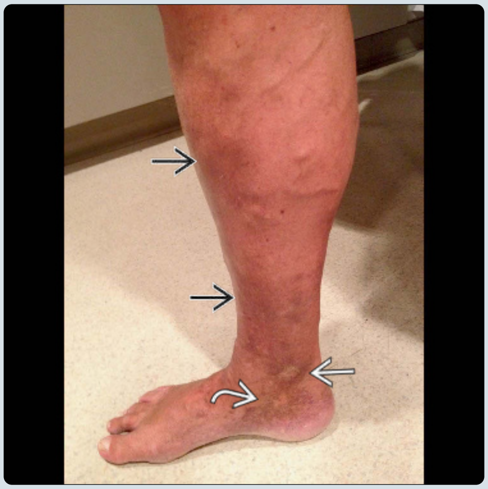


(Left) *Duplex US shows reflux* ↪ *in the great saphenous vein (GSV), indicating retrograde flow due to valvular incompetence, thus causing venous insufficiency. Clinically significant reflux lasts > 0.5-1.0 seconds.* **(Right)** *Image of the right leg (A) before great GSV thermal ablation shows multiple varicose veins* ⇨ *in the GSV distribution. Six months following ablation (B), the varicose veins are no longer present.*

Endovenous Laser Ablation (Micropuncture Venous Access)



Clinical Manifestations (Healing of Ulceration Post Treatment)



(Left) *US shows the tip of the microaccess needle* ➡ *within the lumen* ➡ *of the GSV, prior to introduction of the wire. If resistance is met during guidewire passage, use US to confirm an intraluminal course.* **(Right)** *Clinical photograph of this patient several months post treatment demonstrates healing of a medial ankle ulceration.* ➡ *Note the areas of pigmentation change* ⇨ *and lipodermatosclerosis* ➡ *characteristic of chronic venous insufficiency.*

TERMINOLOGY

Definitions

- **Endovenous thermal ablation (EVTA)**: Procedure involving internal thermal energy delivery to vein wall
    - Vein irreversibly occludes, eventually fibroses
    - Used to eliminate incompetent superficial truncal veins responsible for superficial venous insufficiency
    - Laser (differing wavelengths) or radiofrequency energy
- **Superficial veins**: Veins of lower extremity superficial to fascia that surrounds muscular compartment
    - Includes truncal veins
        - Great saphenous vein (GSV)
        - Small saphenous vein (SSV)
    - Includes anastomoses connecting GSV/SSV
        - Vein of Giacomini: Posteromedial branch of GSV
        - Anterior thigh tributary (ATT)
            - Arises at SFJ; courses over anterior thigh
    - Also includes innumerable venous tributaries known as collecting veins
- **Superficial venous insufficiency**: Usually caused by primary degenerative disease of superficial vein wall
    - Leads to venous reflux/chronic venous hypertension
- **Venous reflux**: Retrograde flow that occurs within veins; defective valves fail to prevent flow reversal
    - Clinically significant reflux lasts for > 0.5-1.0 seconds following release of compression on muscular mass below vein
- **CEAP classification**: **C**linical status, **e**tiology, **a**natomy, and **p**athophysiology
    - Summarizes disease state in chronic venous disease based on physical observations of disease severity
    - Helps report clinical success of intervention
    - Venous severity score (VSS) is additional means of grading spectrum of disease severity

PREPROCEDURE

Indications

- **Clinical**
    - Symptoms of lower extremity venous insufficiency affecting quality of life
        - Pain, aching, throbbing, heaviness, fatigue, pruritus, night cramps, restlessness, swelling
        - Persistence of symptoms/lack of improvement despite conservative measures
            - Medical grade compression stocking trial warranted as initial conservative treatment
    - Skin changes of chronic venous hypertension
        - Corona phlebectasia, lipodermatosclerosis, atrophie blanche pigmentation
    - Healed or active ulceration
    - Bleeding, extensive bruising
    - Edema
    - Superficial thrombophlebitis
- **Anatomic**
    - Ultrasound documented venous reflux in GSV or SSV
    - Treatment of incompetent superficial truncal veins in setting of deep vein reflux is safe
        - Reflux occurring in deep veins often related to deep system overload by incompetent truncal veins

Contraindications

- Pregnancy or nursing
- Obstructed deep venous system inadequate to support venous return after EVTA
- Active deep vein thrombosis
- Nontraversable vein segments due to extreme tortuosity
- Venous outflow obstruction causing lower extremity venous insufficiency; address prior to EVTA
    - Iliac vein compression (May-Thurner)
    - Iliocaval thrombosis

Preprocedure Imaging

- **Ultrasound**
    - Primary imaging modality used to evaluate suspected venous insufficiency & valvular incompetency
    - Thorough evaluation of venous system with duplex US key to treatment success
        - Evaluate anatomy, physiology, patency, and reflux
            - Assess deep/superficial veins
            - Assess perforating veins
        - Perform in standing position
        - Establish pattern of disease and plan treatment
- **Magnetic resonance venography (MRV)**
    - Useful for evaluation of pelvic venous anatomy in selected cases
        - Suspected venous outflow obstruction
    - Useful for evaluation of lower extremity venous anatomy in selected/complex cases
        - Anatomic display of superficial truncal veins
    - Gadofosveset trisodium [Ablavar (Lantheus; N. Billerica, MA)] useful as MRV contrast agent
        - Gadolinium-based contrast agent; contains 70% less gadolinium than all other MRA contrast agents
        - Has high degree (~ 85%) of albumin-binding
            - Results in extended intravascular retention
        - Ideal for vascular imaging compared to other agents that are rapidly cleared from blood
            - Very useful for imaging venous system

Getting Started

- Things to check
    - Complete medical history of current venous issues
        - Symptoms worse with prolonged standing/sitting
        - Most noticeable at end of day
        - Prior history of venous thrombosis
        - Family history of venous insufficiency/varicosities
    - Previous history of conservative management
        - Compression stocking trial
        - Response to conservative management
    - Previous venous surgery/interventions
        - May complicate EVTA procedure
    - Comorbidities, medications, allergies, pertinent family history
    - Complete physical examination below waist
        - Visible vein abnormalities
        - Edema of extremities
        - Skin hyperpigmentation, corona phlebectasia, eczema, lipodermatosclerosis, ulceration
    - CEAP score of patient
    - Photographs helpful to document severity/extent

- Medications
  - Tumescent anesthesia (~ 0.1% lidocaine)
    - Delivery of large volumes of dilute local anesthetic agent to create large region of anesthesia
      - Mix 30 mL 1% lidocaine/250 mL normal saline (NS); add 20 mL NS (300 mL total volume)
      - Can be cooled to increase heat sink effect, protect surrounding perivenous structures
    - Amount of local anesthetic agent used should follow patient's body weight recommendations
      - Up to 5 mg lidocaine/kg of body weight
  - 1% lidocaine; local skin anesthesia for initial access
- Equipment list
  - Thermal energy source: Laser or radiofrequency generator
  - Kit containing energy-depositing catheter
  - Protection eyewear: Laser-specific attenuating glasses for operator, patient, staff in room when appropriate
  - Marking pen
  - Povidone-iodine or chlorhexidine skin cleanser
  - Micropuncture kit
  - Duplex ultrasound unit
  - Sterile ultrasound probe cover and gel
  - Klein pump: For administering tumescent anesthesia (if available)
  - 25-g or 22-g 1.5" long needles
  - Scalpel
  - Absorbent gauze, elastic bandages
  - Fitted waist-high or thigh-high graduated compression stockings

PROCEDURE

Patient Position/Location

- Supine with access to medial thigh
- Prone if SSV to be treated

Procedure Steps

- **General**
  - Reconfirm/map venous insufficiency location/extent with US before placing patient on table
    - Determine optimal site for accessing GSV or SSV
    - Access lowest incompetent venous segment, avoiding lower 1/3 of calf
      - Reverse Trendelenburg position may facilitate
  - Use marking pen to mark area to be treated
  - Sterilely prepare/drape treatment area
  - Administer local anesthetic at intended access site
  - Access vein with micropuncture set using US
  - Introduce 0.018" microwire & transitional dilator
    - Exchange microwire for 0.035" guidewire
    - Some kits allow introduction of delivery sheath over 0.018" guidewire
  - Pass guidewire centrally beyond saphenofemoral junction (SFJ)/saphenopopliteal junction (SPJ)
    - If guidewire enters varicosities/side branches rather than coursing in saphenous vein
      - Try different guidewire (e.g., angled glidewire)
      - Monitor with US while advancing guidewire
  - Make small skin incision to introduce EVTA device
  - Place vascular introducer sheath over guidewire
  - Using US, advance ablation device via introducer sheath to most central location of vein to be treated
    - Ensure tip not positioned in deep venous system
    - Tip ideally 2-3 cm below SFJ when treating GSV
    - For SSV ablation, position tip at cephalad end of SSV before it passes below muscular fascia
  - With treatment catheter in place, deliver perivenous tumescent anesthesia using pump (if available)
    - Use US to position anesthesia needle beside vein
    - Create circumferential halo of fluid surrounding saphenous vein
      - Extrinsically compresses/empties vein
      - Improves thermal transfer to vein wall
      - Separates vein from surrounding structures, insulating while providing anesthesia
  - Reconfirm catheter tip position with US prior to treatment
  - Activate and slowly withdraw catheter, ensuring enough energy deposition per segment treated
  - Apply manual compression to vein entry site to gain hemostasis after device removal
  - Perform adjunctive phlebectomy/sclerotherapy at this time if indicated
- **Endovenous laser ablation (EVLA)**
  - Laser wavelengths: 810, 940, 980, 1064, 1320, 1470 nm
    - Newer 1,470 nm wavelength targets water, effective vein specific heating
    - Some designs prevent contact with vein wall (VenaCure NeverTouch, AngioDynamics, Latham, NY)
  - Continuous energy delivery ranging from 6-14 watts
  - Almost no treatment failures using at least 70 J/cm (40 J/cm for 1,470 nm fiber)
- **Radiofrequency ablation (RFA)**
  - ClosureFAST RF catheter (Medtronic, Minneapolis, MN)
    - 7-cm ablation segment with 20-second treatment
    - Delivers 95-120°C thermal energy
  - Minimal pain, tenderness, bruising
    - Controlled heating believed to avoid venous perforations; less perivenous inflammation

Alternative Procedures/Therapies

- Radiologic
  - Sclerotherapy, liquid or foam
    - 1% or 3% sodium tetradecyl sulfate (STS) (Sotradecol)
      - Physician compounded (mixed) with room air
      - Nontumescent, nonthermal
    - 1% polidocanol foam (Varithena, BTG International, West Conshohocken, PA)
      - Commercially prepared and supplied [proprietary microfoam-generating device with O_2:CO_2 (65:35) gas mixture with < 0.8% nitrogen]
      - Nontumescent, nonthermal
  - n-butyl-2-cyanoacrylate (n-BCA)-based formulation (VenaSeal, Medtronic, Minneapolis, MN)
    - Proprietary adhesive delivered via a dedicated device
    - Nontumescent, nonthermal, nonsclerosant
    - Compression stockings not requirement post procedure
- Surgical
  - Surgical vein stripping

  - Transilluminated Powered Phlebectomy System (Trivex, LeMaitre Vascular, Burlington, MA)
- Other
  - Conservative treatment with compression stockings

POST PROCEDURE

Things to Do

- Adequate dressing critical step in follow-up care (thermal ablation)
  - Wrap leg with sterile gauze, high elasticity bandage
  - Waist-high or thigh-high graduated compression stocking (at least 20-30 mm Hg) should be worn
- Encourage patient to ambulate immediately post procedure, as much as possible at home
- Discourage more vigorous exercise for 1-2 weeks
- Use NSAIDs for pain control and antiinflammatory
- Daytime compression stocking for 2- to 4-week period
- Counsel patient regarding expectations/outcomes

Postprocedure Imaging

- Follow-up ultrasound of treated extremity
  - Should obtain within at least 4 weeks of treatment
  - Should evaluate treated venous segment(s)
    - Confirm occlusion of treated venous segment
    - Evaluate varicosities arising from treated segment
      - May predict need for adjunctive procedures (e.g., sclerotherapy, ambulatory phlebectomy)
  - Should include evaluation of deep venous system
    - Exclusion of DVT
    - Evaluation of status of deep system reflux if was present prior to saphenous vein ablation
      - May completely resolve or may improve after successful saphenous vein ablation

OUTCOMES

Problems

- Superficial phlebitis of untreated varicosities possible
- Most cephalad 10-15 cm of GSV most susceptible to treatment failure
- Persistence of varicosities, despite satisfactory EVTA treatment of GSV or SSV
  - May be due to failure to treat refluxing anterior thigh tributary vein or Giacomini vein
  - May be due to outflow obstruction such as May-Thurner anatomy, iliocaval thrombosis

Complications

- Most feared complication(s)
  - Deep venous thrombosis (1-2% incidence)
  - Skin burn (1-4% incidence)
- Immediate/periprocedural complication(s)
  - Injury to saphenous or sural nerves can result in postoperative pain/paresthesias (5-10% incidence)
  - Infection including superficial thrombophlebitis, wound infections, cellulitis (2-10% incidence)
- Delayed complication(s)
  - Treatment failures including vein recanalization
- Other complications
  - Endovenous heat-induced thrombus (EHIT): Postoperative propagation of thermally induced GSV/SSV thrombus into femoral or popliteal vein
    - Has different US characteristics from those of spontaneously occurring thrombus
      - Becomes echogenic in < 24 hours
      - Often regresses/completely resolves (7-10 days)
    - Some investigators administer perioperative anticoagulation as prophylaxis for DVT/EHIT

Expected Outcomes

- Extremely high technical & clinical success rates for both laser and radiofrequency GSV/SSV ablation
  - Majority of treatment failures occur before 1 year
- Excellent symptom relief/low recurrence rate
  - Improvement of visible varicosities; lessening or resolution of leg pain
- Bruising/tightness, peaking 4-7 days post treatment
- Promising results from more recently approved therapies
  - Varithena polidocanol foam sclerotherapy
  - VenaSeal n-butyl-2-cyanoacrylate (n-BCA) closure of GSV

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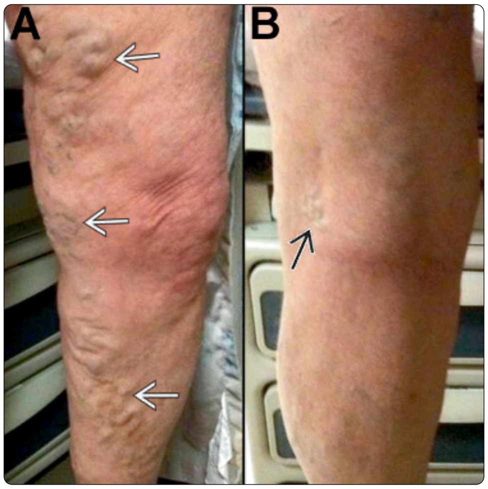
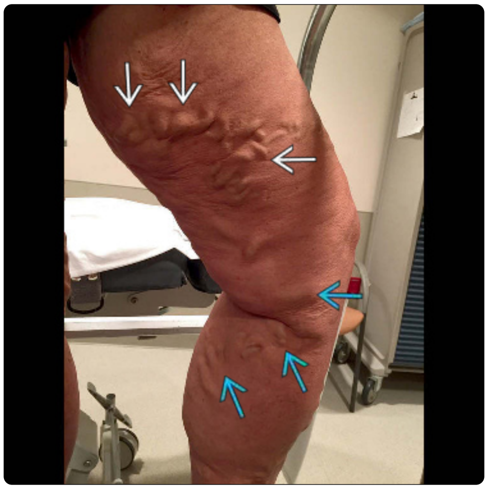
(Left) *Photographs are useful for documentation prior to and following intervention. (A) This patient has large varicosities* ➡ *localizing along the GSV course. (B) Having fewer posterior varicosities* ⇒ *is typical of GSV disease.* **(Right)** *Clinical photograph demonstrates large, superficial varicosities arising from an incompetent great saphenous vein in the thigh* ➡*. The varicosities bridge the knee and extend into the medial calf* ⇒*.*

Clinical Manifestations (Varicosities in GSV Distribution)

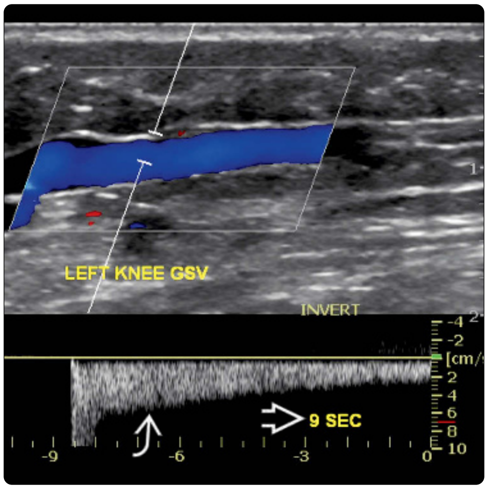


Clinical Manifestations (Varicosities Due to GSV Incompetence)

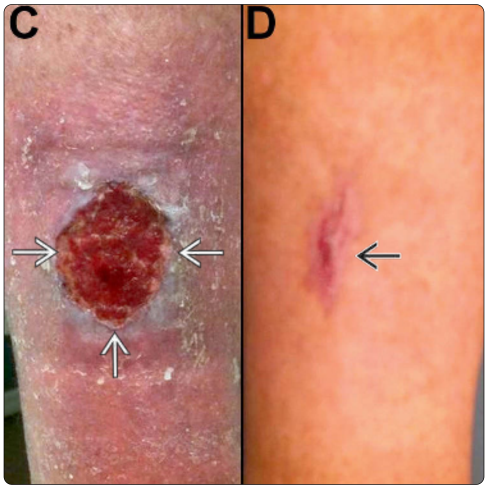


(Left) *Color Doppler US in a patient with symptomatic varicosities shows severe GSV reflux* ↪ *lasting 9 seconds* ⇨*. If reflux is absent in the GSV, other etiologies for the varicosities, such as incompetent perforators, should be considered.* **(Right)** *(C) Venous stasis ulcers* ➡ *are a sequela of severe venous insufficiency, and will not heal without eliminating the underlying venous reflux disease. (D) After saphenous vein ablation, this ulcer* ⇒ *demonstrated healing.*

Preprocedural US Imaging (Evaluation for GSV Reflux)

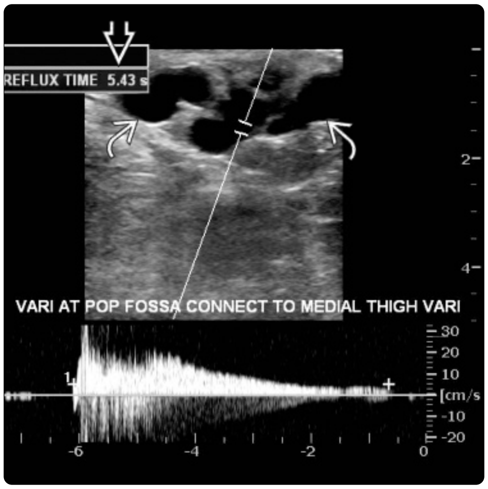


Clinical Manifestations (Venous Stasis Ulcer)

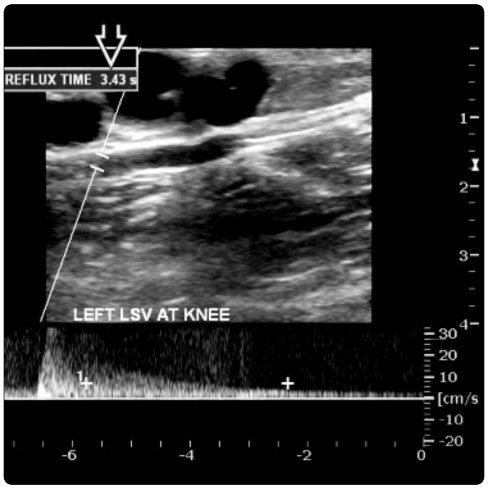


(Left) *This patient has varicosities* ↪ *visible in the popliteal fossa exhibiting significant reflux* ⇨*. These are continuous with medial thigh varicosities arising from the GSV.* **(Right)** *The small saphenous vein should always be included as part of the Doppler evaluation of lower extremity venous insufficiency. This is particularly important when popliteal fossa or posterior calf varicosities are present, as these may be caused by an incompetent SSV. Here, the SSV shows > 3 seconds of reflux* ⇨*.*

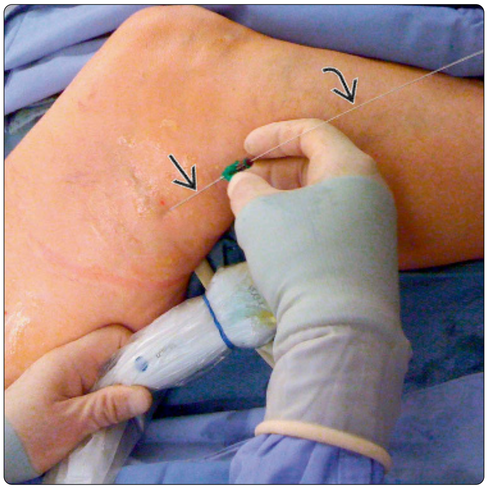
Preprocedural US Imaging (Evaluation for Variceal Reflux)



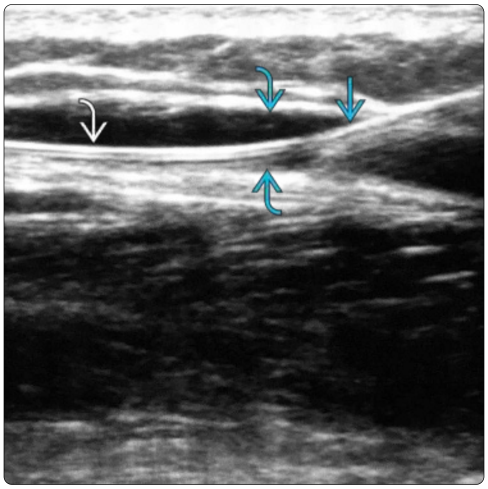
Preprocedural US Imaging (Evaluation for SSV Reflux)



Endovenous Laser Ablation (Micropuncture Venous Access)

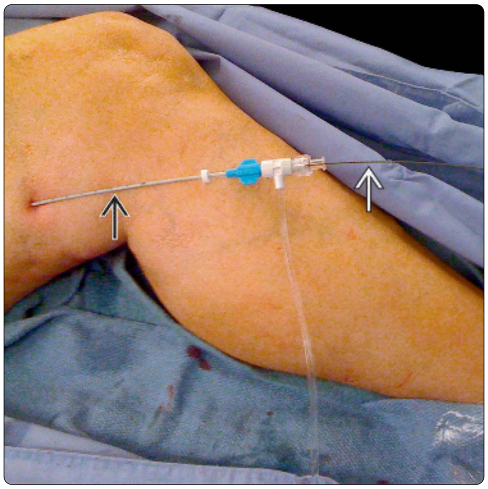


Endovenous Laser Ablation (Micropuncture Venous Access)

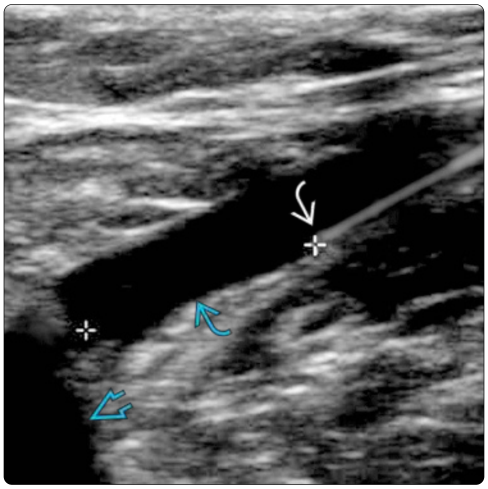


(Left) *An intraoperative photograph shows that a micropuncture needle ⇨ has been used to access the left GSV above the knee, using ultrasound guidance, and an 0.018" wire ↪ has been introduced.* **(Right)** *US demonstrates access of the great saphenous vein. The micropuncture needle ⇨ is seen within the lumen of the GSV ↪. The 0.018" microwire ➡ is seen clearly to be within the vein lumen as well.*

Endovenous Laser Ablation (Placement of Calibrated Sheath)

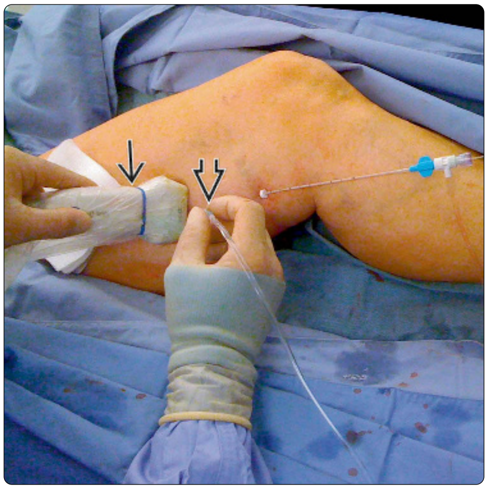


Endovenous Laser Ablation (Positioning of Laser Fiber Tip)

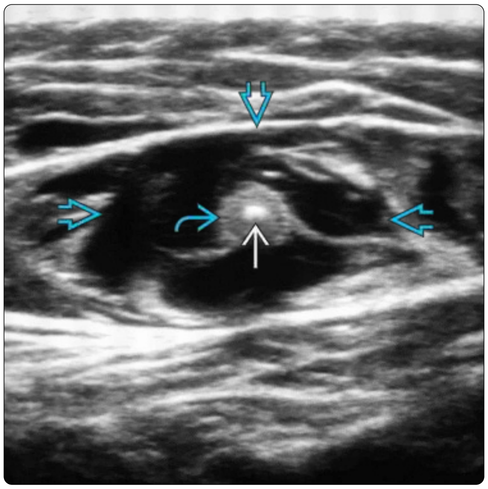


(Left) *Intraoperative photograph demonstrates the calibrated sheath ⇨ introduced over the guidewire ➡. The sheath has been advanced beyond the saphenofemoral junction. The guidewire and inner dilator will be removed and replaced with the laser fiber.* **(Right)** *Sagittal US shows the GSV ↪ and common femoral vein ⇨. The laser fiber tip ➡ is positioned 2-3 cm proximal to the saphenofemoral junction. Careful tip positioning minimizes the chances of causing femoral vein DVT.*

Endovenous Laser Ablation (Tumescent Anesthesia Delivery)

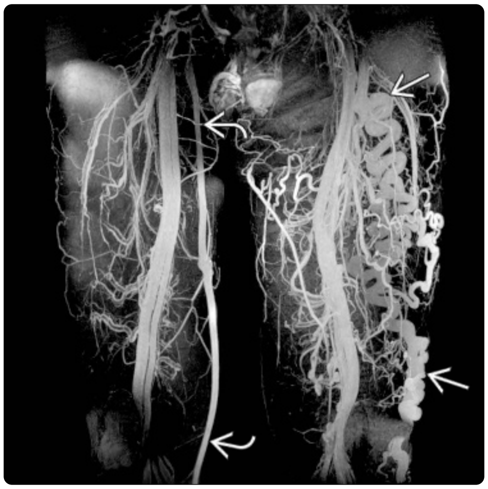


Prior to Ablation (Tumescent Anesthesia Delivery)

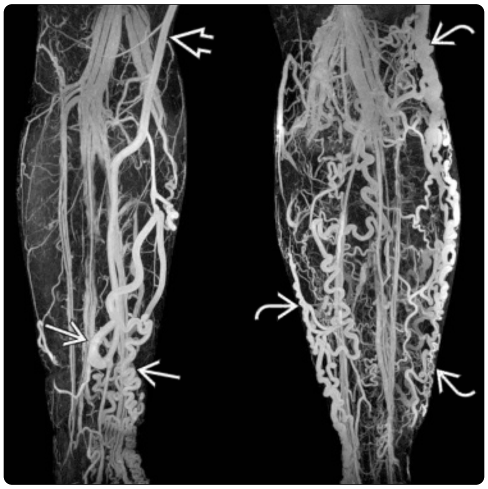


(Left) *Intraoperative photograph shows delivery of tumescent anesthesia ⇨, which is a solution of dilute (~ 0.1% lidocaine), buffered local anesthetic, delivered via an infusion pump with real-time US guidance ⇨.* **(Right)** *US demonstrates the echogenic sheath and laser fiber ➡ within the compressed great saphenous vein ↪, surrounded by a sonolucent halo ⇨ of circumferential tumescent anesthesia.*

(Left) *CEMRV may be valuable for adjunctive imaging in cases of complex venous anatomy that is poorly defined by US. In this case, despite prior left GSV stripping, there are large thigh varicosities ➡ that arise from an anterior thigh tributary (ATT) & Giacomini veins. The right GSV ⇨ is still present.* **(Right)** *MRV of both calves shows large right varicosities ➡ arising from the GSV ➡ and extensive left calf varicosities ⇨ that are perfused by the ATT and Giacomini veins. Complex venous anatomy such as this is well demonstrated by MRV.*

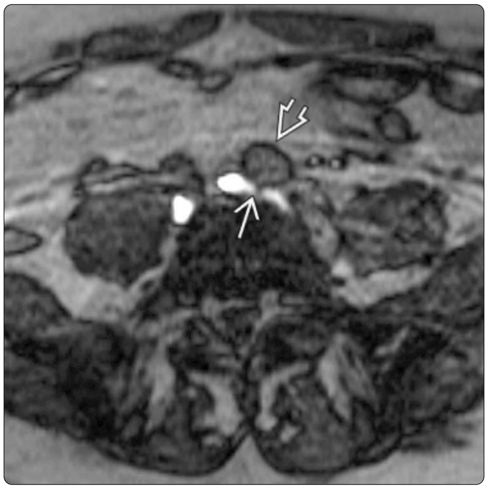


Alternative Imaging With MRV (Anatomic Evaluation of Thigh Veins)

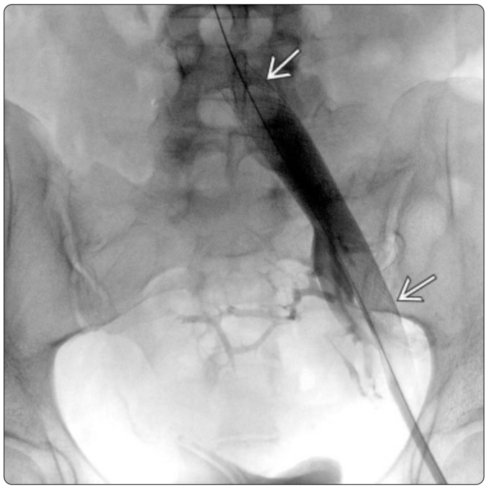


Alternative Imaging With MRV (Anatomic Evaluation of Calf Veins)

(Left) *Saphenous vein ablation to eliminate varicosities due to GSV reflux may fail if there is abdominal or pelvic venous outflow obstruction. Axial MRV shows extrinsic compression of the left iliac vein ➡ between the vertebra and left common iliac artery ➡, c/w variant May-Thurner anatomy. Typically, the right common iliac artery causes the compression.* **(Right)** *A left iliac vein stent ➡ was placed after intravascular ultrasound (IVUS) confirmation of outflow obstruction. Subsequent GSV thermal ablation was clinically successful.*

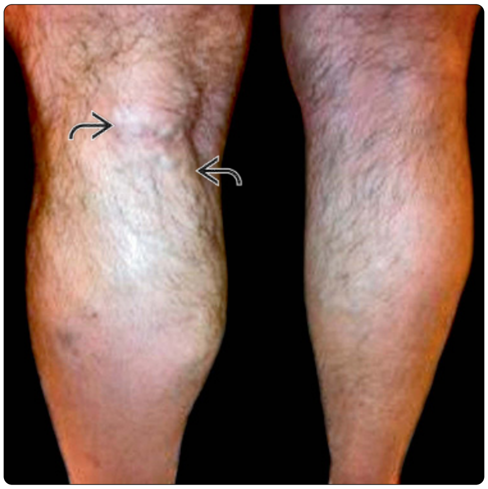


Pelvic Venous Outflow Obstruction (MRV Evaluation of Pelvic Veins)

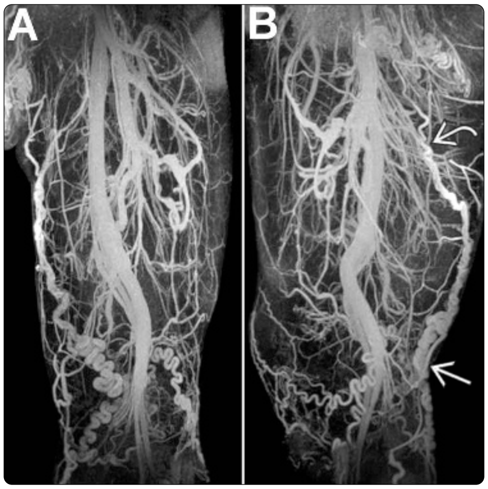


Pelvic Venous Outflow Obstruction (Left Iliac Vein Stent Placement)

(Left) *Photograph of a different patient 4 weeks after GSV ablation shows left leg swelling with large varicose veins ⇨ in the popliteal fossa. Although the patient had resolution of his medial thigh varicosities, there was persistent calf pain & swelling.* **(Right)** *Left leg MRV using gadofosveset trisodium contrast was performed to further evaluate the superficial venous system. (A) Coronal and (B) Sagittal 3D MRV shows that there is a Giacomini vein ➡ that is perfusing the popliteal fossa varicosities ➡.*

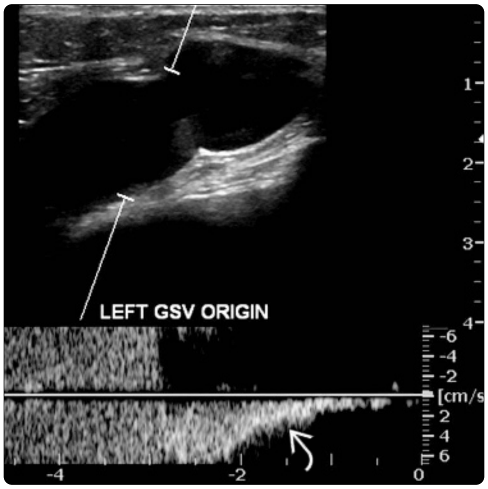


Persistent Postablation Varicosities (Refluxing Vein of Giacomini)

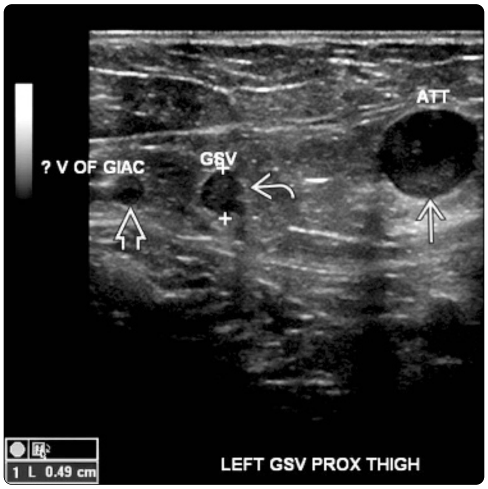


Persistent Postablation Varicosities (Refluxing Vein of Giacomini)

Failure of GSV Ablation (Saphenofemoral Tributary Reflux)

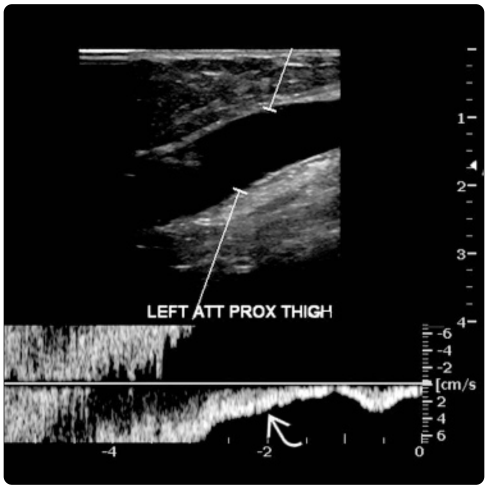


Failure of GSV Ablation (Anterior Thigh Tributary Vein)

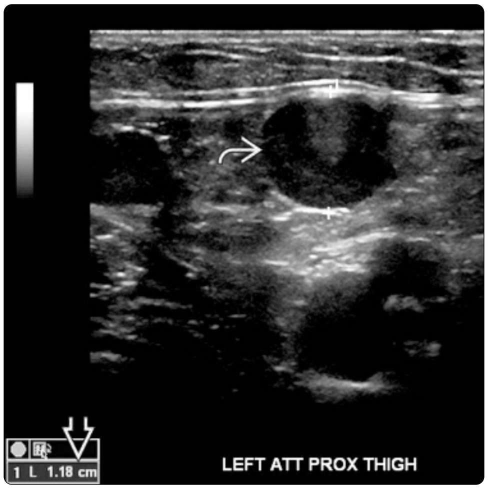


(Left) *There are accessory superficial venous tributaries that may join with the great saphenous vein near the saphenofemoral junction. These tributaries may exhibit reflux and may be an alternate source of varicosities. In this patient, there is a patulous GSV origin with marked reflux* ↪*.* **(Right)** *Axial US of the proximal thigh, just inferior to the saphenofemoral junction, shows that the ATT vein* ⇨ *is much larger than the great saphenous vein* ↪*. A small Giacomini vein* ⇨ *is also present.*

Failure of GSV Ablation (Anterior Thigh Tributary Reflux)

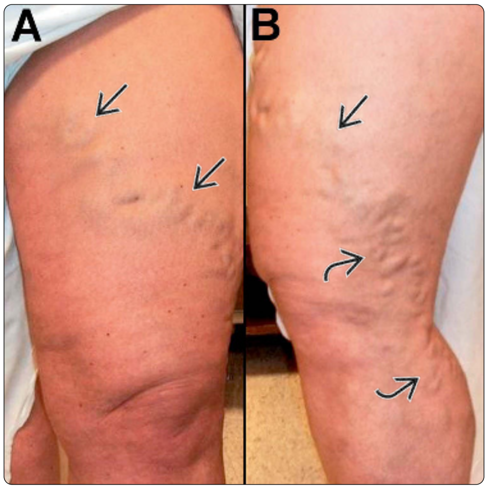


Failure of GSV Ablation (Anterior Thigh Tributary Vein)

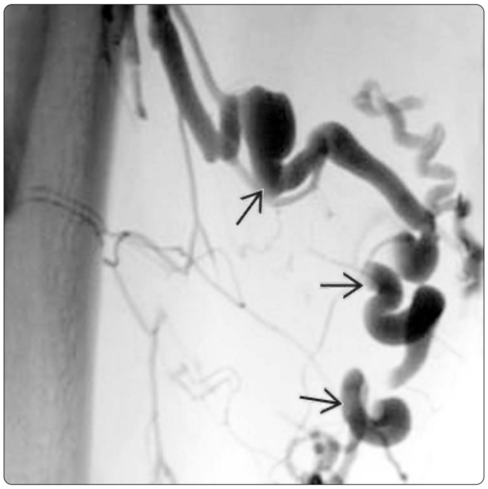


(Left) *Doppler US of the anterior thigh tributary vein demonstrates marked reflux* ↪*, confirming persistent venous insufficiency. If the GSV is ablated and an abnormal ATT remains, the symptomatic varicose veins may not resolve.* **(Right)** *Axial US slightly more inferiorly shows that the anterior thigh tributary vein* ↪ *is markedly dilated and measures > 1 cm in diameter* ⇨*. In this particular patient, the incompetent tributary vein is the dominant etiology for the varicose veins.*

Failure of GSV Ablation (Anterior Thigh Tributary Vein)



Failure of GSV Ablation (Anterior Thigh Tributary Vein)



(Left) *Clinical photograph in (A) frontal and (B) lateral projections shows the enlarged and tortuous anterior thigh tributary vein* → *and varicosities* ↪*. This is the typical distribution of the ATT and associated varicosities.* **(Right)** *AP contrast venography also shows the tortuous anterior tributary vein* →*. Currently available thermal ablation technology requires a relatively straight course to the target vein for device passage. In cases such as this, sclerotherapy or phlebectomy are appropriate alternatives.*

Vascular Malformations

KEY FACTS

TERMINOLOGY

- **Vascular malformation (VMF)**: Most common vascular anomaly consisting of abnormal clusters of blood vessels, without endothelial proliferation
  - **Low flow**: Capillary, venous (VM), lymphatic (LM) or "mixed" malformations
  - **High flow**: Direct artery to vein communication
- Classification
  - **International Society for the Study of Vascular Anomalies (ISSVA) classification (revised 2014)**
    - Most widely recognized classification system based on cellular features, flow characteristics, associated clinical features and genetics
  - **SE Mitchell Vascular Anomalies Flow Chart**
    - Combines clinical and imaging findings for accurate VMF diagnosis
  - **Yakes classification**
    - Organizes AVMs by angioarchitecture and ascribes endovascular treatment options for each subtype

PREPROCEDURE

- Combination of MR, CT, US, and angiography used to diagnose and classify VMF
- In addition to imaging to diagnose and characterize lesion, patients should undergo hematologic testing that includes complete blood count, coagulation panel as well as (for VM) D-dimer and fibrinogen

PROCEDURE

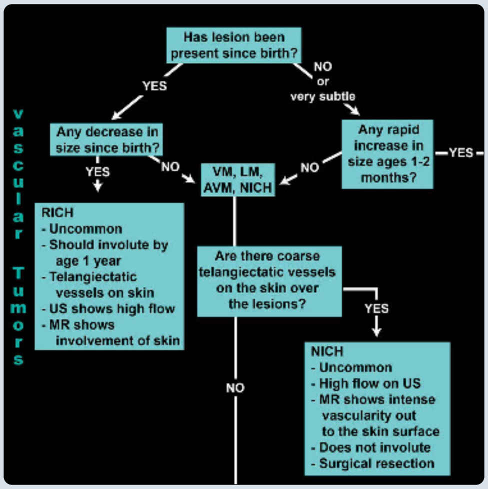
- AVM: Embolization can be performed for treatment
- VM and LM: Sclerotherapy can be performed
- AVF: Most spontaneously resolve within few months, serial imaging and clinical evaluation often sufficient

OUTCOMES

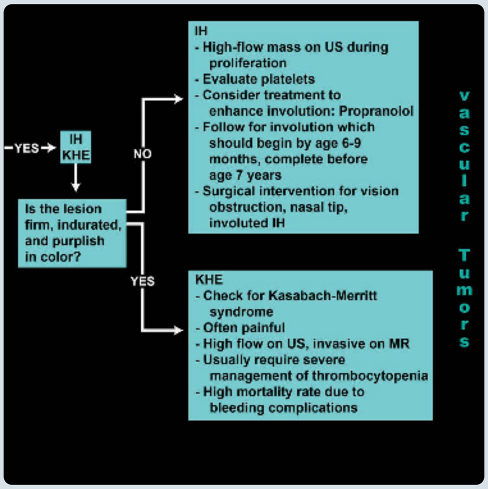
- VM: 65% total occlusion 6 mo after foam sclerotherapy
- LM: Mixed results with sclerotherapy; cure rare
- AVM: 80% of patients have significant improvement in clinical symptoms after embolization

(Left) *The SE Mitchell Vascular Anomalies Flow Chart (SEMVAFC) is shown. Abbreviations are defined as follows: VM = venous malformation; LM = lymphatic malformation; AVM = arteriovenous malformation; NICH = noninvoluting congenital hemangioma; RICH = rapidly-involuting congenital hemangioma.* **(Right)** *The SEMVAFC (continued) is shown. Abbreviations are defined as follows: IH = infantile hemangioma; KHE = kaposiform hemangioendothelioma.*

SE Mitchell Vascular Anomalies Flow Chart: Vascular Tumors (I)

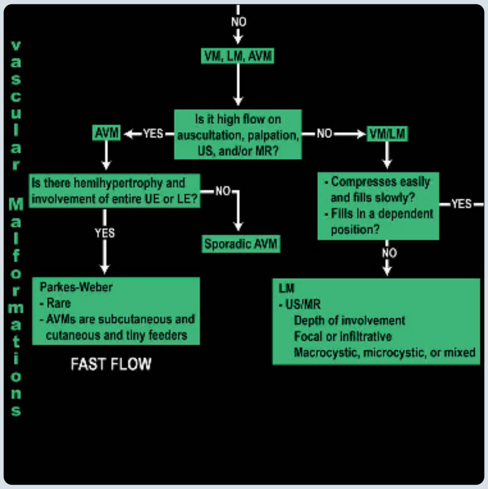

Vascular Tumors
Has lesion been present since birth?
YES
NO or very subtle
Any decrease in size since birth?
YES
NO
RICH
- Uncommon
- Should involute by age 1 year
- Telangiectatic vessels on skin
- US shows high flow
- MR shows involvement of skin
VM, LM, AVM, NICH
NO
Any rapid increase in size ages 1-2 months?
YES
Are there coarse telangiectatic vessels on the skin over the lesions?
YES
NO
NICH
- Uncommon
- High flow on US
- MR shows intense vascularity out to the skin surface
- Does not involute
- Surgical resection

SE Mitchell Vascular Anomalies Flow Chart: Vascular Tumors (II)

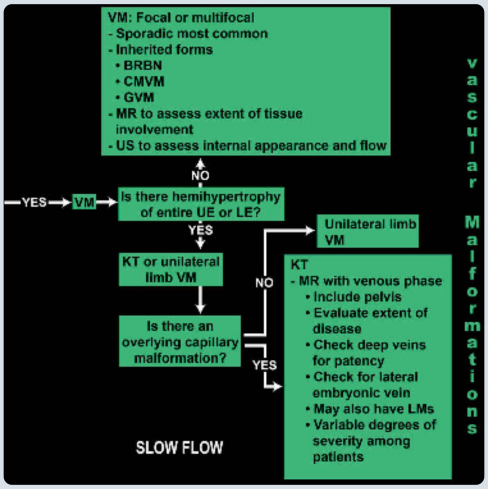

YES
IH KHE
Is the lesion firm, indurated, and purplish in color?
NO
YES
IH
- High-flow mass on US during proliferation
- Evaluate platelets
- Consider treatment to enhance involution: Propranolol
- Follow for involution which should begin by age 6-9 months, complete before age 7 years
- Surgical intervention for vision obstruction, nasal tip, involuted IH
KHE
- Check for Kasabach-Merritt syndrome
- Often painful
- High flow on US, invasive on MR
- Usually require severe management of thrombocytopenia
- High mortality rate due to bleeding complications
Vascular Tumors

(Left) *The SEMVAFC (continued) is shown. Abbreviations are defined as follows: UE = upper extremity; LE = lower extremity.* **(Right)** *The SEMVAFC (continued) is shown. Abbreviations are defined as follows: BRBN = blue rubber bleb nevus syndrome; CMVM = cutaneous-mucosal venous malformation; GVM = glomuvenous malformation; KT = Klippel-Trénaunay syndrome.*

SE Mitchell Vascular Anomalies Flow Chart: Vascular Malformations (I)


Vascular Malformations
NO
VM, LM, AVM
Is it high flow on auscultation, palpation, US, and/or MR?
AVM
YES
NO
VM/LM
Is there hemihypertrophy and involvement of entire UE or LE?
NO
YES
Sporadic AVM
- Compresses easily and fills slowly?
- Fills in a dependent position?
YES
NO
Parkes-Weber
- Rare
- AVMs are subcutaneous and cutaneous and tiny feeders
FAST FLOW
LM
- US/MR
Depth of involvement
Focal or infiltrative
Macrocystic, microcystic, or mixed

SE Mitchell Vascular Anomalies Flow Chart: Vascular Malformations (II)


VM: Focal or multifocal
- Sporadic most common
- Inherited forms
• BRBN
• CMVM
• GVM
- MR to assess extent of tissue involvement
- US to assess internal appearance and flow
NO
YES
VM
Is there hemihypertrophy of entire UE or LE?
YES
KT or unilateral limb VM
Is there an overlying capillary malformation?
NO
YES
Unilateral limb VM
KT
- MR with venous phase
• Include pelvis
• Evaluate extent of disease
• Check deep veins for patency
• Check for lateral embryonic vein
• May also have LMs
• Variable degrees of severity among patients
SLOW FLOW
Vascular Malformations

TERMINOLOGY

Definitions

- **Vascular malformation (VMF)**: Most common vascular anomaly consisting of abnormal clusters of blood vessels without endothelial proliferation
  - **Low flow**: Capillary, venous, lymphatic or "mixed" malformations
    - **Venous malformations (VM)**
      - Most common type of VMF consisting of dilated venous vessels with abnormal smooth muscle, which allows for expansion of VM over time
      - May or may not communicate with systemic vasculature
      - Usually sporadic but can occur as part of genetic syndrome (e.g., Klippel-Trénaunay)
      - Diverse range of size, location, and appearance: From small, solitary, and localized to skin and subcutaneous tissues to diffuse masses extending across multiple tissue planes and surrounding vascular, nervous, and visceral bodies
    - **Lymphatic malformation (LM)**
      - 2nd most common VMF consisting of benign cystic lesions made up of lymphatic vessels filled with lymphatic fluid
      - Most commonly sporadic; however, some associated with genetic syndromes (e.g., Turner, Noonan)
      - Classified based on cyst size as macrocystic (large), microcystic (small), or mixed
      - Previously used terms such as lymphangiomas and cystic hygromas should be avoided
    - **Capillary malformation (CM)**
      - Limited to superficial skin layers, formerly called port-wine stains
      - Can darken, thicken, and become nodular if left untreated
      - Often associated with congenital syndrome (e.g., Sturge-Weber, Parkes Weber, Klippel-Trénaunay)
  - **High flow**: Direct communication between arteries and veins
    - **Arteriovenous malformations (AVM)**
      - Complex communicating network of arterial and venous vessels
      - Typically more invasive than other VMFs
      - Arterial inflow diverted via nidus into draining veins, causing tissue ischemia and venous hypertension
      - High recurrence rate after treatment with total nidus eradication considered "curative"
    - **Arteriovenous fistula (AVF)**
      - Direct abnormal communication between artery and vein without interposed nidus
      - Can be acquired (most common) or congenital
      - Limb ischemia can occur distal to AVF due to arterial blood shunted via fistula (steal phenomenon)
  - **Syndromes associated with VMFs**
    - **Klippel-Trénaunay syndrome**: VM combined with LM and CM
    - **Parkes Weber syndrome**: VM combined with LM, CM, and AVM
    - **Sturge-Weber syndrome**: Cutaneous CM along distribution of facial and ocular nerves; leptomeningeal vascular anomalies (CM, VM)

Classification

- **International Society for the Study of Vascular Anomalies (ISSVA) classification (revised 2014)**
  - Most widely recognized classification system based on cellular features, flow characteristics, associated clinical features and genetics
  - Defines common language used by all members of interdisciplinary teams involved in care of vascular anomalies
  - Broadly divides vascular anomalies into nonneoplastic lesions (VMFs) and neoplastic lesions (vascular tumors)
- **SE Mitchell Vascular Anomalies Flow Chart (SEMVAFC)**
  - Combines clinical and imaging findings for accurate VMF diagnosis
  - Utilizes classification schema similar to ISSVA to preserve common language
  - Potential to identify syndromes associated with VMF
- **Yakes classification**
  - Organizes AVMs by angioarchitecture and ascribes specific endovascular treatment options for each subtype

Low-Flow Malformations: Clinical Features

- Presentation & physical exam
  - **VM**
    - Present as soft, compressible, nonpulsatile, bluish lesions
    - Often present with pain, swelling, and depending on location, mechanical dysfunction or cosmetic disfigurement
    - Vary in size and distribution; potentially involves multiple anatomic locations
    - Majority are solitary but can be associated with genetic syndrome (e.g., blue rubber bleb nevus syndrome)
    - Can occur in any anatomic depth (i.e., skin, subcutaneous tissue, muscle, etc.) and are often infiltrative and extend to underlying or nearby structures
    - Placement of affected area in dependent position or Valsalva maneuver may elicit blood pooling and subsequent enlargement of lesion
    - Most commonly occur in head, neck, and extremities but can present anywhere on body
  - **LM**
    - Present as soft, nonpulsatile, uniocular or multilocular cystic lesions
    - Often present with swelling, and depending on location, mechanical dysfunction or cosmetic disfigurement
    - Can become swollen and painful when locally infected or with systemic infection
    - Vary in size from microcystic to macrocystic (> 1-2 cm) or mixed type
    - Can be isolated or associated with genetic syndrome (e.g., Turner, Noonan)
    - Most often present in head and neck, but chest, axilla, and perineum also common sites

- **CM**
    - Present as pink-red patches but may darken, thicken, and become more nodular with time
    - Can be isolated or coexist with other VMFs, or associated with genetic syndrome (e.g., Kippel-Trénaunay, Sturge-Weber, Parkes Weber)
    - Physical exam and, in some cases, imaging should exclude underlying malformations

High-Flow Malformations: Clinical Features, Noncerebrovascular

- Presentation and physical exam
    - **AVM**
        - Present as warm, palpable mass with ill-defined border and reddish discoloration of overlying skin
        - Surrounding fat tissue most often present
        - Often accompanied by palpable thrill/bruit
        - Most commonly present in limbs, trunk, and viscera
        - Bleeding, ulceration of surrounding soft tissue and high-output heart failure in advanced stages
        - May cause "steal" from surrounding or downstream organs
        - May lead heart failure due to high cardiac output
    - **AVF**
        - Present as palpable, pulsatile mass often associated with bruit and perivascular thrill
        - Only congenital AVFs classified as VMFs: Most are acquired (e.g., traumatic or iatrogenic)
        - Congenital AVFs are rare, can occur anywhere in body and commonly manifest in infancy as high-output heart failure
        - Claudication, deep vein thrombosis, rest pain, and varicose veins may develop in extremities distal to lesion

PREPROCEDURE

Preprocedure Imaging

- **Low-flow malformations**
    - MR
        - Often used for initial evaluation in children with advantages of wide availability, patient comfort, lack of ionizing radiation, diagnostic ability in prenatal settings, and real-time hemodynamic characterization
        - Low-flow lesions appear as low echogenicity with monophasic low-velocity or completely absent flow detection
        - Compression or Valsalva maneuver may be helpful during US to induce flow
        - Phleboliths in areas of calcification within lesion may be seen, suggesting VM
        - Useful to guide sclerotherapy procedures for low-flow vascular anomalies and for postprocedural imaging to assess vasculature in close proximity to treated lesion
        - Helpful when attempting to distinguish between hemangioma (vascular tumor) vs. VMF
        - Disadvantages include limited field of view, difficulty delineating full extent of malformation
    - US
        - Initial evaluation with advantages of wide availability, patient comfort, lack of ionizing radiation, and real-time hemodynamic characterization
        - Useful to guide sclerotherapy procedures for low-flow vascular anomalies and for postprocedural imaging to assess vasculature in close proximity to treated lesion
        - Limited utility in larger VMFs due to small field of view
        - Color Doppler US may differentiate between high-flow & low-flow VMFs
            - Venous malformation: Compressible, hypoechoic/heterogeneous mass
            - May see venous reflux in dysplastic veins
            - May have anechoic regions with no/slow flow
        - Operator-dependent modality that should be carried out by trained technologist and monitored by radiologist to ensure reliability
    - CT
        - Limited utility for low-flow VMF
    - Lymphatic imaging
        - Radioisotope lymphoscintigraphy has limited utility
    - DSA
        - Limited utility for low-flow VMF
- **High-flow malformations**
    - CTA
        - Preferred method for assessing large AVMs given large field of view, ability to assess lesion extent and proximity to crucial structures as well as feeding arteries and draining veins
    - MR
        - Another preferred method for assessing large AVMs given large field of view, ability to assess lesion extent and proximity to crucial structures
        - MRA preferable to conventional MR for AVFs with ability to visualize early filling of draining vein
        - AVMs: T1- and T2-hypointense serpiginous signal voids (flow-voids) with enhancement during arterial phase of MRA with contrast
        - DCE-MRA used to assess feeding arteries and draining veins and reveals early venous filling in arterial phase
        - Conventional angiography most accurate in identifying and differentiating nidus, feeding arteries, and draining veins
        - Edema, fibrin deposition, and tissue overgrowth may be apparent in adjacent tissues
    - US
        - Feeding artery demonstrates high-velocity diastolic blood flow with low-resistance waveforms
        - Draining vein will demonstrate high-velocity pulsatile arterialized flow
        - Perivascular thrill may be present
    - DSA
        - Critical for treatment planning
            - Used to assess the nidus, feeding arteries, and draining veins and to determine approach/plan technique
            - Treatment planning typically useful after treatment delivery to assess residual disease

Getting Started

- Things to check
    - Careful history and physical examination should be performed for any patient being considered for sclerotherapy

- In addition to imaging to diagnose and characterize lesion, patients should undergo hematologic testing that includes complete blood count, coagulation panel as well as (for VM) D-dimer and fibrinogen
    - Patients with elevated D-dimer (> 5x upper limit) and low fibrinogen defined as having localized intravascular coagulopathy (LIC) and should be referred for hematology consult
        - Patients typically placed on LMWH (Lovenox) 10 days pre- and postintervention

Treatments: Low-Flow Malformations

- **Noninvasive**
    - Compression garments that decrease blood stagnation to treat limb swelling and extremity pain
    - Aspirin and low molecular weight heparin (LMWH) to decrease risk of thrombotic complications
    - Sirolimus (rapamycin) may be efficacious and safe in treatment of extensive LM and VM refractory to other therapies
    - Laser photocoagulation and electro-optical synergy techniques effective in treatment of skin-based lesions
- **Sclerotherapy**
    - Refers to direct injection of sclerosants into cystic spaces of VMFs resulting in inflammatory response consisting of thrombosis, fibrosis, and eventual contraction of lesion
    - Sclerosants (VM)
        - Ethanol is most commonly used sclerosant
            - Highly effective, careful use important to avoid complications
            - Risks include nerve damage, skin burns, and significant swelling postprocedure
            - Total EtOH dose should not be > 1 cc/kg administered no faster than 0.1 cc/kg per 5 min to avoid cardiovascular complications
            - Other common agents include: 3% sodium tetradecyl sulfate (typically foamed with air and Lipiodol) and polidocanol
            - Similar risks to ethanol
            - Total dose of 3% sodium tetradecyl sulfate liquid should not exceed 0.5 cc/kg
    - Bleomycin (often foamed with air) is novel agent that has shown to be effective for treatment of VMs
        - Does not cause thrombosis or inflammation and is particularly useful in head and neck and when VM involves tendons
        - Risks include persistent rash; all skin irritation needs to be avoided for 48 h after use of Bleomycin
        - Lifetime Bleomycin dose limit of 400 units should be observed due to risk of pulmonary fibrosis
- Sclerosants (LM)
    - Doxycycline
        - Either single injection administrations or serial exchanges via indwelling catheters
    - Bleomycin (often foamed with air)

Treatments: High-Flow Malformations

- AVM
    - AVM embolization is one of most complex procedures to perform; these notes are rudimentary/educational only
    - Preprocedure preparation
    - Includes similar work-up as described in low flow
- Embolization (general approaches)
    - Arterial
        - Main AVM feeder artery selected, then using microcatheter, distal feeder arteries subselected
        - Goal to position catheter into very distal feeding branch proximal to nidus
        - Once in position as close to nidus as possible, embolization material can be injected/deployed (i.e., EtOH, glue, Onyx, coils)
    - Venous
        - Most successful approach when single draining vein
        - Similar to arterial approach, goal is to get as close to nidus as possible
        - Occluding balloon distal to site of embolization may be employed to prevent nontarget embolization
        - Once in position as close to nidus as possible, embolization materials deployed (i.e., EtOH, glue, Onyx, coils)
    - Direct needle puncture
        - This approach can be employed if paucity of arterial feeders or draining veins
        - Direct puncture into nidus performed and embolic agents delivered/deployed (i.e., EtOH, glue, Onyx, coils)
        - Postprocedural care
            - As ~ 98% of AVMs will enlarge or recur within 5 years, frequent clinic visits within this period are necessary
            - Additional interventions indicated if symptoms return

PROCEDURE

Procedure Steps

- **General**
    - Informed consent obtained
    - Patient asked to localize lesion with 1 finger and site marked
    - Anesthesia is induced
    - Preprocedural US performed to visualize VM
    - Patient prepped and draped in sterile fashion
    - US guidance used to percutaneously access venous malformation
        - Access into malformation obtained with 4 or 7 cm with 21-gauge needle then is connected to flexible tubing and 3 cc syringe with contrast
    - Successful access confirmed with blood return (VM) or lymph return (LM)
    - Presclerotherapy DSA venograms performed to characterize VM; presclerotherapy contrast filling documented (LM)
- **VM**
    - If large draining vein identified, manual compression can be used to prevent sclerosant from traveling to systemic vasculature
    - Glue or coils may be required to occlude large draining veins if needed
    - Double needle technique can also be used to reduce risk of rupture
        - Double needle technique requires placement of 2 needles within VM: 1 to inject sclerosant and other to decompress malformation

Yakes Classification

Type	Description	Treatment
I	Direct single AVF	Mechanical occlusion devices (e.g., plugs, coils)
IIa	Multiple arteries into nidus with multiple outflow veins (typical AVM nidus)	
IIb	Typical AVM nidus with shunt into outflow aneurysmal vein	
IIIa	Multiple AVFs into wall of single outflow aneurysmal vein	Coiling of aneurysmal single outflow vein
IIIb	Multiple AVFs into wall of aneurysmal vein with multiple outflow tracts	Coiling of each outflow vein
IV	Diffuse interstitial AVF that infiltrates tissue or organ with associated capillary beds	Transcatheter embolization combined with direct puncture embolization

AVM = arteriovenous malformations . Yakes classification organizes AVMs by angioarchitecture and ascribes specific endovascular treatment options for each subtype.

Vascular Malformations ISSVA Classification

Simple	Combined
Capillary malformation (C)	Capillary-venous (CVM), capillary-lymphatic (CLM)
Lymphatic malformation (LM)	Lymphatic-venous (LVM), capillary-lymphatic-venous (CLVM)
Venous malformation (VM)	Capillary arteriovenous (CAVM)
Arteriovenous malformation (AVM)	Capillary-lymphatic arteriovenous (CLAVM)
Arteriovenous fistula	Capillary-venous (CVAVM), capillary-lymphatic-venous (CLVAVM)

ISSVA Classification of Vascular Anomalies 2014 International Society for the Study of Vascular Anomalies

  - Sclerosant agent injected into each accessed site of VM under fluoroscopic guidance using negative contrast technique
  - Sclerosant should be left to dwell within VM for 15-20 min
  - After dwell time, administration syringe disconnected and needle observed for venous return
  - If venous return observed, another DSA should be performed and sclerosant injection should be repeated followed by final 15-20 min dwell
  - When administering Bleomycin, no thrombosis expected, and reassessment and retreatment not necessary
  - Needle(s) removed and gentle pressure applied to access site if needed
- **LM**
  - LM sac drained completely and ~ 50% volume of sclerosant administered (typically doxycycline)
  - Needle(s) removed and gentle pressure applied to access site if needed
  - For larger LM sacs, small 5- to 6-Fr locking drain can be placed in LM over wire and ~ 50% volume of sclerosant (doxycycline) administered
  - Patient then admitted for serial doxycycline exchanges until fluid volume return becomes negligible, at which time malformation is drained percutaneous drains removed
- **AVM**
  - General embolization principles outlined above in treatments for high-flow malformations section
- **AVF**
  - As acquired AVFs most often spontaneously resolve within few months, serial imaging and clinical evaluation often sufficient
  - Congenital and large AVFs that persist require surgical or endovascular repair (e.g., endovascular placement of covered stent over fistula or placement of coils or plugs into fistula tract)

POST PROCEDURE

Things to Do

- Ice packs can be applied postprocedurally and tight circumferential dressings avoided
- Steroids may be indicated to reduce swelling, especially if treated lesion occurred on face/neck or extremity susceptible to compartment syndrome
- Most patients admitted overnight post sclerotherapy for observation and pain management
- Patients typically seen in clinic ~ 1 week post sclerotherapy
- Follow-up MR/clinic should be done at 6-10 weeks post sclerotherapy to assess treatment response
- Multiple treatment sessions may be required for larger more complicated lesions
- Patients should return annually and sooner if symptoms return

OUTCOMES

Complications

- Most feared complication(s)

  - Nontarget embolization
    - More problematic with certain embolic agents
      - ☐ Liquids (e.g., ethanol, sclerosants)
      - ☐ Particles
    - Avoid by using superselective catheterization/occlusion of inflow &/or outflow of lesion
  - Cardiopulmonary collapse requiring resuscitation
    - Rare but serious sequela of ethanol embolization
    - Due to increased pulmonary arterial pressure
  - Compartment syndrome
    - Avoid by limiting sclerosant agent volume
    - Perform frequent postprocedure monitoring
  - Pulmonary embolus
  - Death
- Immediate/periprocedural complication(s)
  - Pain
  - Inflammation of vessels
  - Transient hemoglobinuria
  - Access site complications
    - Hematoma, pseudoaneurysm, iatrogenic AVF formation
- Delayed complication(s)
  - Deep vein thrombosis
  - Skin/subcutaneous tissue injury: Up to 11.9%
    - Skin blistering/erythema
    - Skin/subcutaneous tissue necrosis
  - Muscle necrosis
  - Peripheral neuropathy: Up to 8.6%
    - Mostly seen in venous malformation treatment

Expected Outcomes

- **AVM treatment**
  - ~ 80% of patients have significant improvement in clinical symptoms after embolization
    - However, < 20% have complete cure
  - 85% success rate treating type II AVMs with ethanol
    - Complex lesions have lower success rates
  - Staged procedures may be necessary, especially in treatment of complex, high-flow malformations
    - Must consider radiation exposure issues
    - Most patients require multiple treatments
- **VM treatment**
  - 65% total occlusion 6 months after foam sclerotherapy
- **LM treatment**
  - Mixed results with sclerotherapy; cure rare

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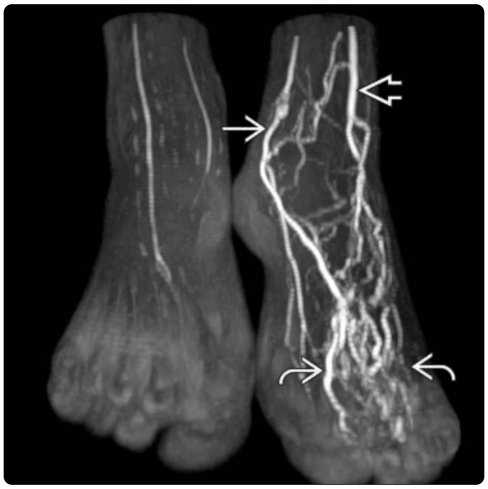
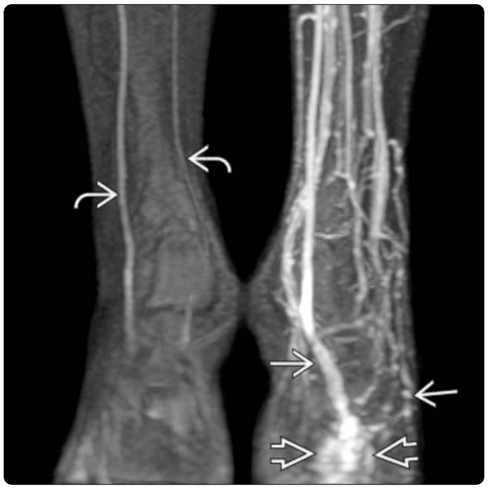
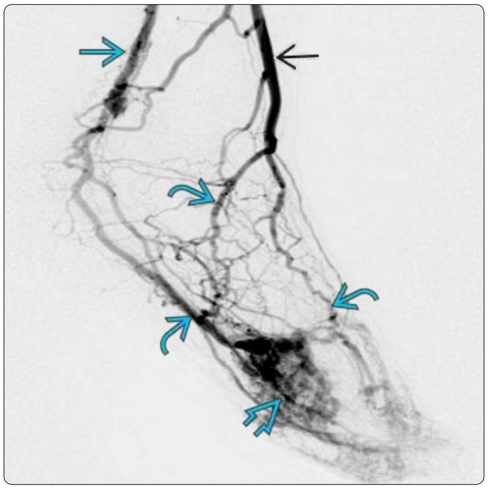
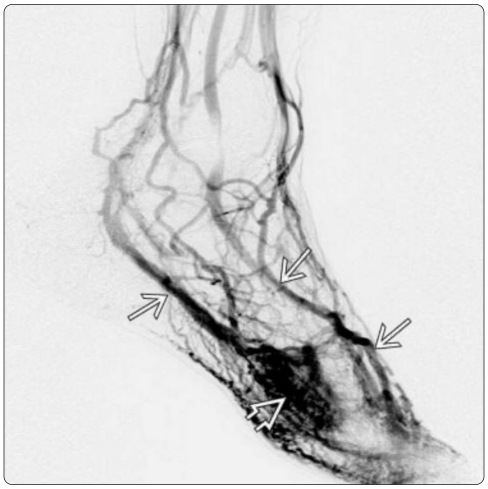
(Left) *3D gadolinium-enhanced MRA in a patient with a pulsatile left forefoot mass shows abnormal vascularity* ➡ *corresponding to the area of tissue loss. The anterior* ➡ *and posterior tibial* ➡ *arteries are enlarged.* **(Right)** *Slightly delayed image shows very prominent veins* ➡ *draining the area of abnormality* ➡ *in the left forefoot, while the arterial phase* ➡ *still persists on the right. The MRA findings are consistent with a high-flow AVM.*


AVM Embolization With Onyx (Initial MRA Evaluation)

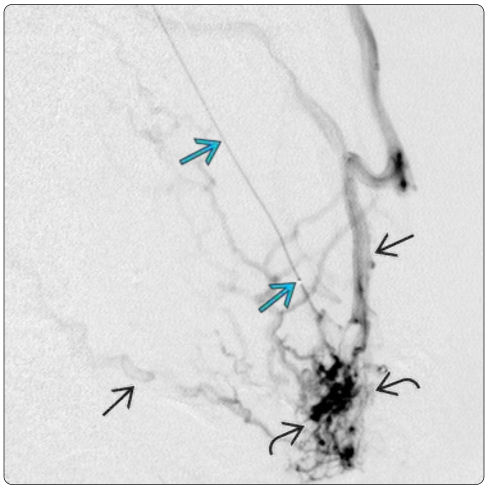

AVM Embolization With Onyx (Initial MRA Evaluation)

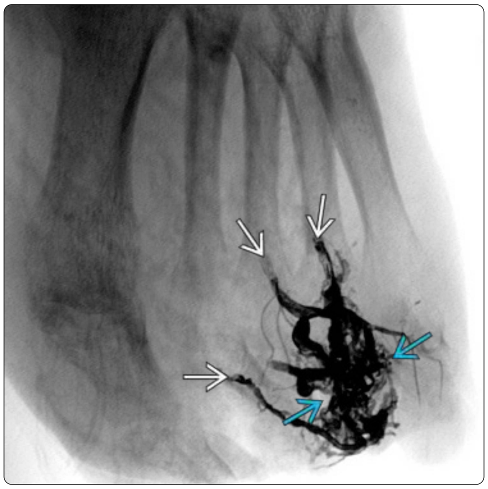
(Left) *Early arterial phase left foot DSA is shown. The anterior* ⇨ *and posterior tibial* ⇨ *arteries are quite enlarged and give off multiple arterial feeders* ⇨ *that supply the nidus* ⇨ *of the high-flow AVM.* **(Right)** *Later image from the DSA shows more dense opacification of the nidus* ➡ *along with very prominent and early draining veins* ➡*. DSA findings confirm that this is a high-flow AVM.*


AVM Embolization With Onyx (Diagnostic DSA Evaluation)

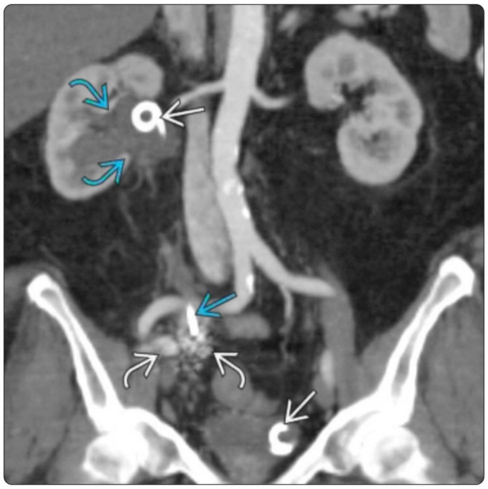

AVM Embolization With Onyx (Diagnostic DSA Evaluation)

(Left) *After placing a 4-Fr catheter in the anterior tibial artery, a coaxial microcatheter* ⇨ *was advanced into the dorsalis pedis artery and positioned in one of the dominant feeders to the AVM. DSA shows the nidus* ⇨ *and multiple draining veins* ⇨*.* **(Right)** *Fluoroscopic spot radiograph after transcatheter embolization shows the Onyx cast filling the nidus* ⇨ *and partially extending into the draining veins* ➡ *of the AVM. Although only a portion of the AVM was treated in this session, the skin ulcer healed.*

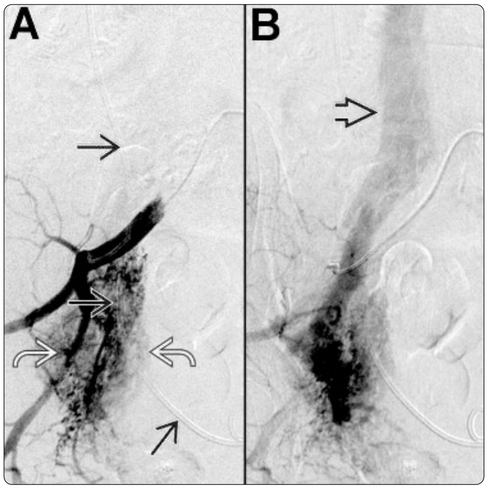

AVM Embolization With Onyx (Coaxial Microcatheter in Nidus)


AVM Embolization With Onyx (Appearance of Onyx Cast in Nidus)

Embolization of Pelvic AVM (Initial CECT Evaluation)

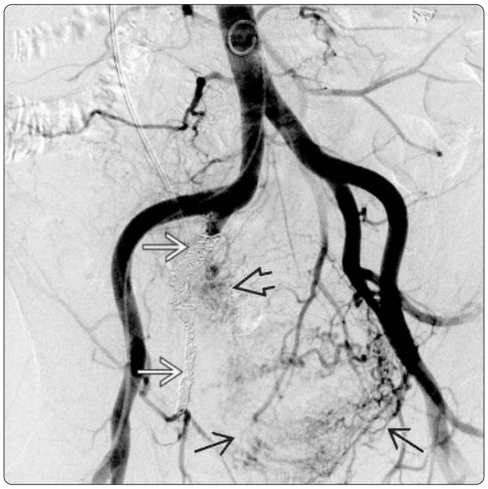


Embolization of Pelvic AVM (Right Internal Iliac Artery DSA)

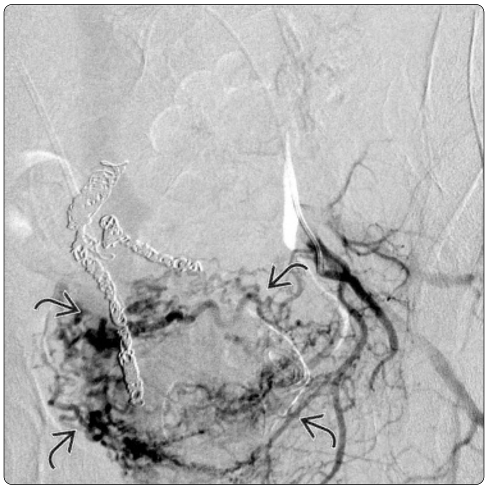


(Left) *This patient with flank pain & hematuria had cystoscopy, which showed an obstructed distal right ureter, with friable bleeding urothelium. A ureteral stent was placed. CECT afterward shows the ends of the ureteral stent* → *& hydronephrosis* ↪*. An enhancing vascular mass* ↪ *surrounds the ureteral stent* → *distally.* **(Right)** *(A) Patient underwent right internal iliac artery DSA showing vascular mass* ↪ *surrounding ureteral stent* →*. (B) Note rapid shunting to IVC* ⇨*. Findings are consistent with high-flow AVM.*

Embolization of Pelvic AVM (DSA After Coil Embolization)

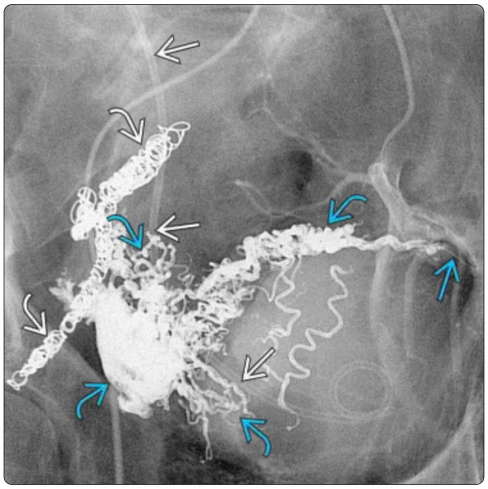


Embolization of Pelvic AVM (Left Internal Iliac Artery DSA)

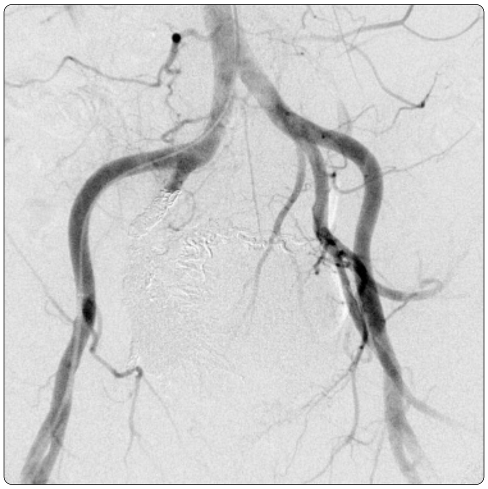


(Left) *The right internal iliac artery was aggressively coil embolized* →*. Unfortunately, the left internal iliac artery was not evaluated for supply to the AVM. As the hematuria failed to improve, the patient underwent repeat DSA, which shows a larger AVM* → *than previously thought, with a minimally changed periureteral component* ⇨*.* **(Right)** *A selective left internal iliac artery DSA shows the extent of the AVM* ↪*.*

Embolization of Pelvic AVM (Onyx Embolization of AVM)



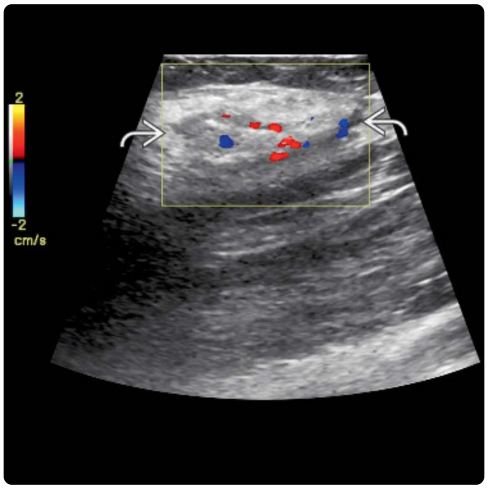
Embolization of Pelvic AVM (Pelvic DSA After Embolization)



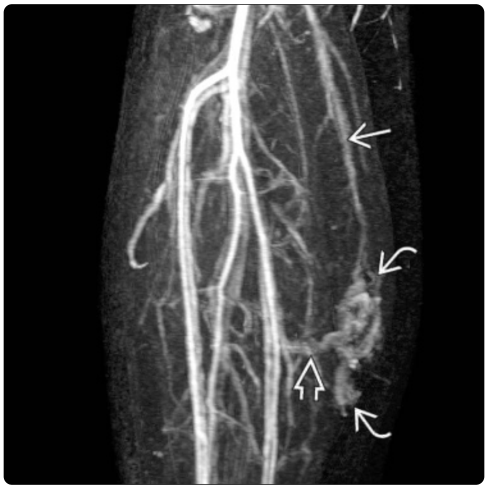
(Left) *A dominant feeding artery was accessible from the left internal iliac artery. A coaxial microcatheter* → *was placed into the feeding artery, and Onyx embolization was performed. A fluoroscopic image after embolization shows an extensive Onyx cast* ↪ *and its relationship to the coils* ↪ *and the ureteral stent* →*.* **(Right)** *Pelvic DSA after Onyx embolization shows that there is no longer any filling of the AVM. This case illustrates the importance of eliminating the nidus in treating an AVM. Coils are rarely effective in achieving this goal.*

(Left) *Color Doppler US of the posteromedial right calf in a patient with localized pain shows a mass-like focus ↪ of slightly increased vascularity. On physical examination, there was no bruit or overlying soft tissue abnormality.* **(Right)** *As a vascular malformation was suspected based on the US findings, the patient underwent gadolinium-enhanced MRA of the right leg. A 3D MR shows a venous malformation ↪ with connections to the deep ⇨ and superficial systems → and no obvious arterial contribution.*

Venous Malformation Sclerotherapy (Color Doppler US Evaluation)

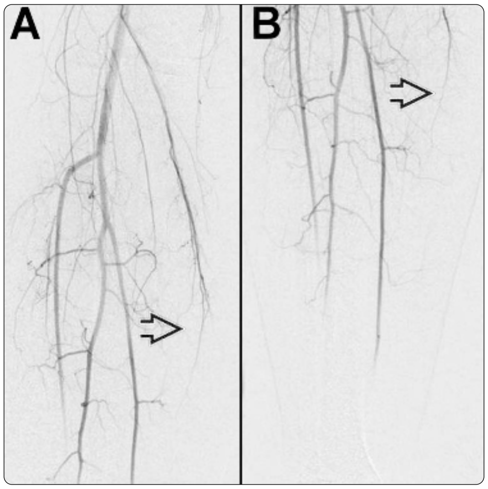


Venous Malformation Sclerotherapy (3D MR Angiography)

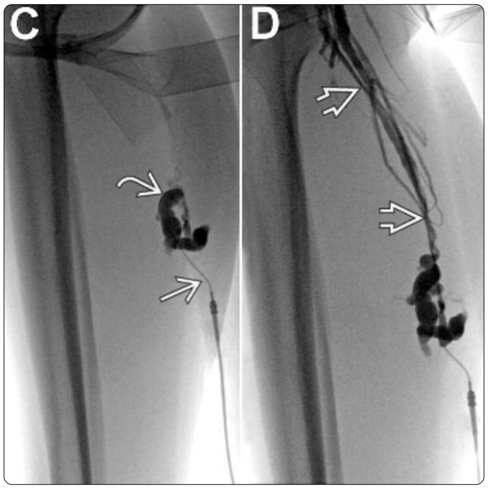


(Left) *To completely exclude any arterial supply to the malformation, prior to treatment, an arterial DSA of the right leg was performed. Images of (A) the upper and (B) lower calf show normal arterial anatomy. In the area of the known mass ⇨, no arterial feeders are seen.* **(Right)** *(C) After direct percutaneous US-guided puncture of the mass, contrast was injected via an angiocatheter →, initially filling the venous malformation ↪ and (D) later opacifying the venous drainage ⇨.*

Venous Malformation Sclerotherapy (Digital Subtraction Angiography)

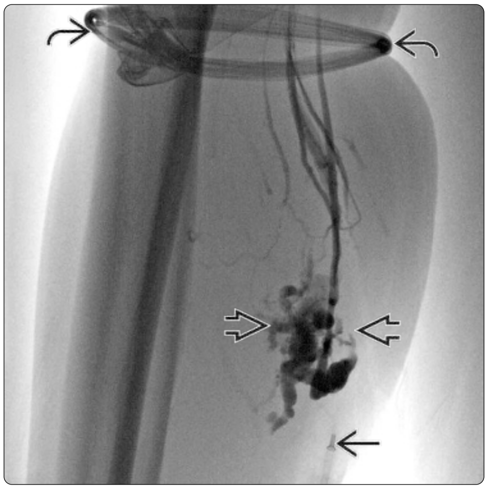


Venous Malformation Sclerotherapy (Direct Percutaneous Venography)

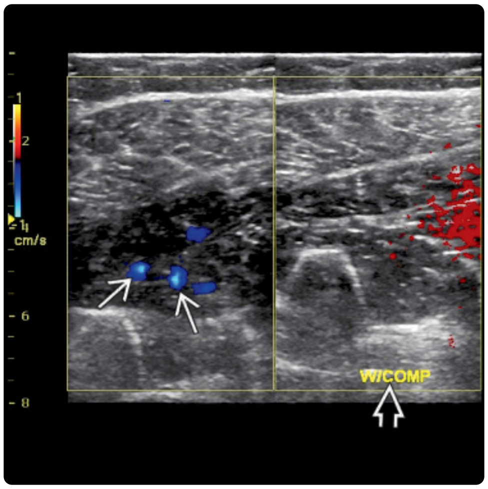


(Left) *After tightly applying a tourniquet ↪ above the malformation ⇨, a mixture of contrast and 3% Sotradecol was slowly introduced via the angiocatheter → and was allowed to remain indwelling for 5 minutes. The volume needed to completely opacify the malformation by venography was used to calculate the appropriate treatment volume.* **(Right)** *After sclerotherapy of the venous malformation, a repeat US was obtained to document results and exclude DVT. The calf veins are patent → and compressible ⇨.*

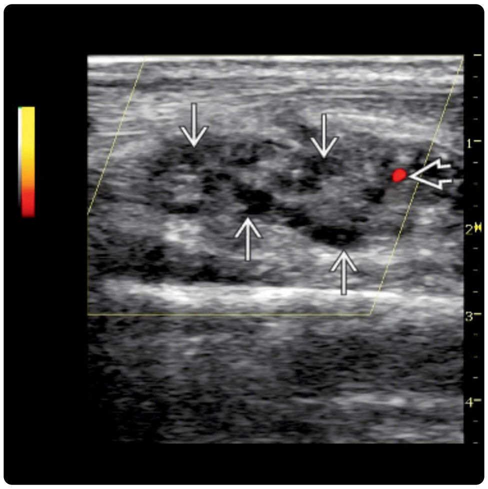
Venous Malformation Sclerotherapy (Injection of Sclerosant)



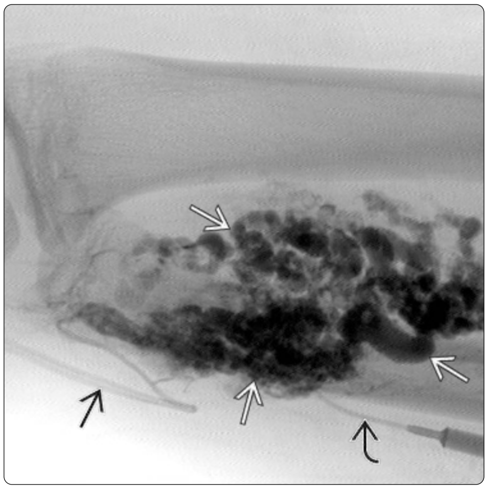
Venous Malformation Sclerotherapy (Color Doppler US After Treatment)



Slow-Flow Malformation Treatment (Initial Color Doppler US)

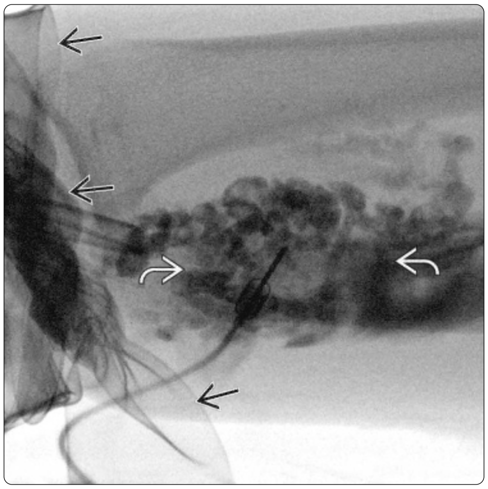


Slow-Flow Malformation Treatment (Direct Puncture & Contrast Injection)

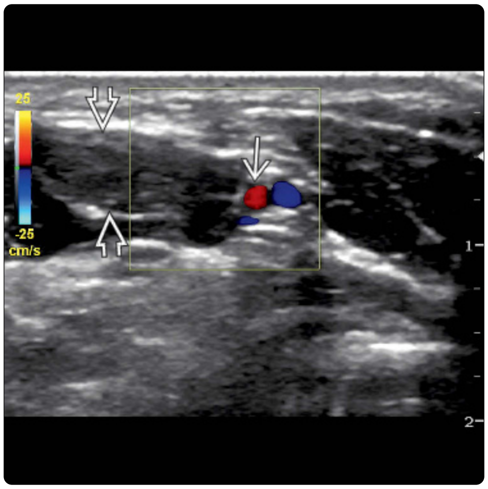


(Left) *Color Doppler US in a patient with a palpable mass in the distal forearm shows anechoic serpiginous channels ➔ that appear vascular but lack color flow, unlike the ulnar artery ⇨. Absence of color signal in the mass is due to very slow flow in this mixed lymphatic-venous malformation.* **(Right)** *The malformation was percutaneously accessed and an angiocatheter ↪ was placed in a large channel. Contrast injection fills the vascular channels ➔ and shows a small communication to the ulnar artery ⇾.*

Slow-Flow Malformation Treatment (Contrast & Sclerosant Injection)

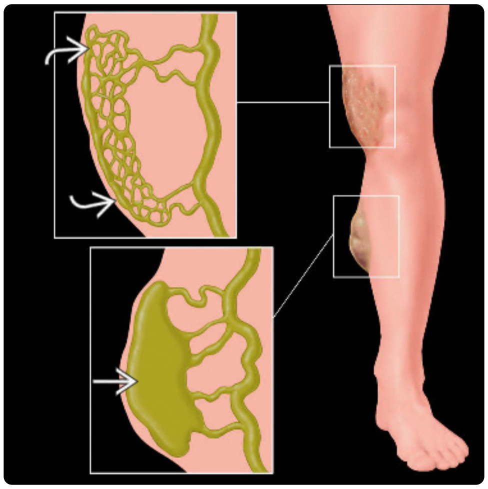


Slow-Flow Malformation Treatment (Color Doppler US After Treatment)

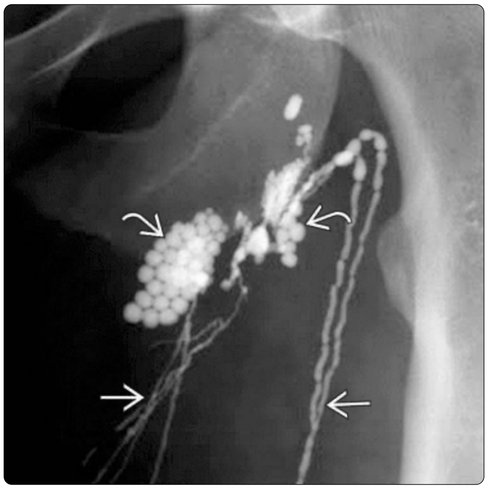


(Left) *A mixture of 3% Sotradecol and contrast was prepared in a 1:1 ratio. After placing a tourniquet ⇾ distally, this mixture was slowly injected into the malformation. Fluoroscopic monitoring was used during injection to confirm complete filling of the malformation ⤷ and no nontarget reflux.* **(Right)** *Color Doppler US 1 week after treatment shows preserved patency of the ulnar artery ➔ and vein along with obliteration of the vascular channels ⇨ that were previously seen.*

Lymphatic Malformations (Classification by Morphology)



Lymphatic Malformations (Lymphangiography of Lymphocele)



(Left) *Lymphatic malformations are sponge-like collections of abnormal lymphatic channels &/or spaces. They are classified as macrocystic ➔ or microcystic ⤷.* **(Right)** *Lymphangiogram performed from the left foot shows Ethiodol filling multiple lymphatic channels ➔ in the thigh, as well as 2 cystic spaces ⤷ in the medial infrainguinal area that represent lymphoceles.*

KEY FACTS

TERMINOLOGY

- **Arteriovenous fistula (AVF)**: Surgical anastomosis between artery and vein
  - Results in maturation: Dilation and arterialization of vein, which becomes amenable to repeated puncture
    - Typically takes 8-12 weeks for maturation
      - ~ 50% never mature
- **Arteriovenous graft (AVG)**: Surgically created connection between artery and vein, using prosthetic conduit
  - Typically constructed from PTFE
  - Newer trilayer AVG (Gore Acuseal) is able to be punctured 24 hours after creation

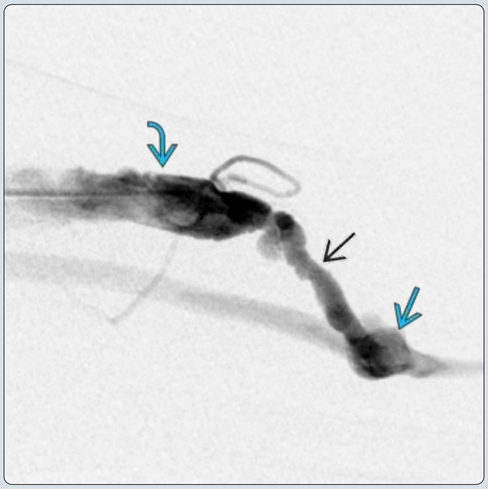
PREPROCEDURE

- Evaluate indication, perform physical examination
  - Abnormalities suggesting outflow stenosis
    - Aneurysmal dilation of access, arm or face swelling, prolonged bleeding, tense/pulsatile access, elevated venous pressures
  - Abnormalities suggesting inflow stenosis
    - Flat, nonvisible or easily collapsible fistula, difficulty with cannulation, weak thrill or bruit
  - Nonlocalizing abnormalities
    - Low Kt/V, low Qa, presence of recirculation
- Check for contraindications
  - Infected access site, elevated potassium, significant coagulopathy

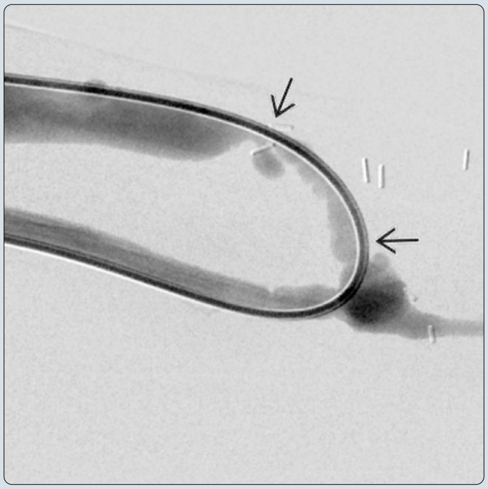
PROCEDURE

- Access away from pointing toward expected site of stenosis
- Evaluate access from upstream artery to right atrium
- Treat stenosis if > 50% and felt to be causing corresponding clinical abnormality
- Conclude procedure, document post intervention physical exam

AVF: Juxtaanastomotic Stenosis (Initial Fistulogram)

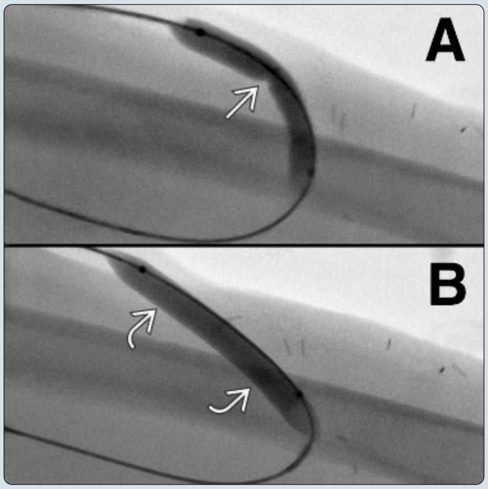


AVF: Juxtaanastomotic Stenosis (Fistulogram From Brachial Artery)

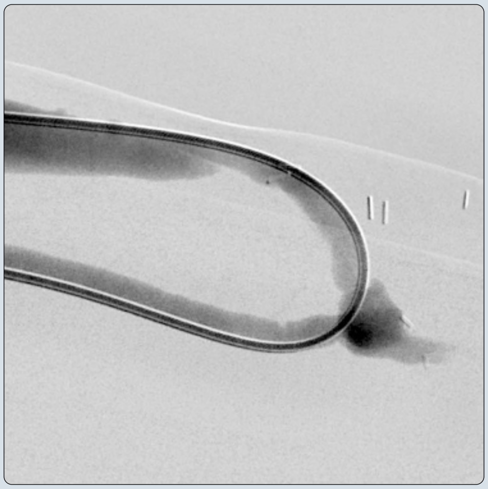


(Left) *This patient was referred for fistula evaluation because of low flows. Physical examination revealed a water-hammer pulse at the anastomosis* ↷ *and an easily compressible main body of the fistula* →*, findings consistent with juxtaanastomotic stenosis. Retrograde puncture was performed, and initial angiogram was done while occluding the outflow, confirming the suspected stenosis* →*.* **(Right)** *The upstream radial artery was cannulated and repeat angiogram again showed the juxtaanastomotic stenosis* →*.*

AVF: Juxtaanastomotic Stenosis (Angioplasty)



AVF: Juxtaanastomotic Stenosis (Postangioplasty)



(Left) *A 6-mm balloon was advanced over the wire to the site of stenosis and inflated. The initial waist* → *(A) was successfully effaced* ↷ *(B).* **(Right)** *Postangioplasty angiogram shows marked improvement in diameter and irregularity of the stenotic segment. Repeat physical exam showed more turgor in the body of the fistula and resolution of the abnormal pulsatility at the anastomosis.*

TERMINOLOGY

Definitions

- **Hemodialysis (HD)**
  - Patient's blood is modified by going through dialyzer
    - Certain solutes are removed
      - e.g., potassium, phosphorus, and urea
    - Dialysate solutes are added
      - e.g., bicarbonate
    - Plasma water often removed
- **End-stage renal disease**
  - a.k.a. chronic kidney disease (CKD) stage 5
  - Glomerular filtration rate (GFR) < 15 mL/min/1.73 m2
  - Need HD, peritoneal dialysis, or kidney transplant for medium-term survival
- **Arteriovenous fistula (AVF)**
  - Surgical anastomosis between artery and vein
    - Results in dilation and arterialization of vein draining fistula
    - Requires maturation period before use
      - Typically 8-12 weeks maturation
      - ~ 50% never able to be used
    - Once mature, less infections and longer lifespan than arteriovenous grafts (AVGs)
  - Common types of AVF
    - **Radiocephalic (RC) fistula (forearm)**
      - Preferred dialysis access
      - Problem: Low rates of maturation
      - Typical site of stenosis: Juxtaanastomotic segment
    - **Brachiocephalic fistula (upper arm)**
      - 2nd preferred dialysis access
      - Used when radial artery or forearm cephalic vein are unsuitable for RC creation
      - Problems: High rate of dialysis-associated steal syndrome (DASS), precludes subsequent ipsilateral forearm fistula creation
      - Typical site of stenosis: Cephalic arch
    - **Brachiobasilic fistula (upper arm)**
      - Used when upper arm cephalic vein unsuitable for AVF creation
      - Problems: Difficult and 2-stage surgery, high rate of steal syndrome
      - Typical site of stenosis: Proximal swing segment
- **Mature fistula**
  - Mature fistula is able to be repeatedly punctured and provide adequate flow for dialysis
  - Satisfies "rule of 6s"
    - Flow > **6**00 mL/min
    - Diameter > 0.**6** cm
    - No more than 0.**6** cm deep
    - Should be mature by **6** weeks
- **Immature fistula**
  - Occurs in > 50% of newly created AVFs
    - Inflow stenosis
      - Most common cause of nonmaturation
      - Does not allow for dilation and arterialization of fistula
    - Competing outflow veins
      - Accessory veins: Naturally occurring branches arising from venous outflow tract; treat with ligation, embolization
      - Collateral veins: Alternative drainage pathways; develop in setting of downstream stenosis; treat by addressing underlying stenosis
    - Fistula that has failed to mature at 6 weeks should trigger further evaluation
- **AVG**
  - Surgically created connection between artery and vein, using prosthetic conduit to provide vascular access for HD treatment
  - Used if unsuitable vascular anatomy for AVF
    - Suitable: Artery > 2 mm in diameter, vein > 2.5 mm in diameter
  - AVG has shorter lifespan than AVF
    - 6-10x greater infection risk and thrombosis
  - Polytetrafluoroethylene (PTFE) graft most frequently used AVG material
    - Can be used within 2-3 weeks of construction
    - Gore Acuseal able to be used 24 hours after creation
  - Types of AVG
    - Loop or straight configuration
      - Forearm preferred over upper arm
      - Arm preferred over groin
    - Prosthetic axillary-axillary arteriovenous straight access (necklace graft)
      - Used for patients with exhaustion of all other upper limb accesses but patent superior vena cava, subclavian and brachiocephalic veins
  - Typical site of stenosis: Graft-vein anastomosis
- **Cephalic arch**
  - Most central portion of cephalic vein
    - Arches through deltopectoral groove to join axillary vein
  - Most frequent site of stenosis in dysfunctional brachiocephalic fistulas (40-77%)
    - Rarely cause of dysfunction in RC fistulas
  - Etiologies of stenosis
    - Extrinsic compression by clavipectoral fascia
    - High concentration of valves in this venous segment
    - Turbulence caused by sharp turn of arch combined with high flow rate
  - Difficult to treat
    - High-pressure balloons often needed
      - Associated high rate of vessel rupture
    - Low primary patency rate at 1 year (~ 20%) with angioplasty alone
- **HeRO graft (hemodialysis reliable outflow)**: Merit Medical
  - Arterial graft component
    - 6-mm inner diameter
    - Material: Expanded polytetrafluoroethylene (ePTFE)
  - Venous outflow component
    - 5-mm inner diameter
    - Radiopaque silicone, reinforced with braided nitinol
  - Titanium connector between arterial graft and venous outflow
  - Used for failing AVF/AVG secondary to central venous stenosis

  - Catheter dependent patients
  - Benefits
    - Lower infection compared to catheters
    - Improved HD adequacy compared to catheters
    - Higher patency rates compared to catheter
- **Qa**: Access flow rate
  - Varies depending on access configuration, presence of stenosis, arterial inflow
- **Qb**: Dialysis pump flow rate
  - Typically set at 350-400 mL/min
- **Kt/V**: Number quantifying dialysis treatment adequacy
  - K: Dialyzer clearance of urea
  - T: Dialysis time
  - V: Volume of distribution of urea, ~ equal to patient's total body water
- **Monitoring**: Periodic physical examination and review of routinely gathered data of dialysis patients performed to detect underdialysis and dysfunctional accesses prior to thrombosis
  - Weekly physical examination
  - Review of routinely gathered data collected during HD
    - Dialysis adequacy: Kt/V
      - Value < 1.2 or decrease by > 0.2 triggers referral for intervention
    - Dynamic pump pressures
      - Unreliable if taken in isolation
      - If abnormal trend or with other access abnormalities can be predictive of the side of stenosis
  - Needling problems
    - Prolonged bleeding suggests outflow stenosis
    - Difficulty with cannulation suggests inflow stenosis
- **Surveillance**: Instrument-based, periodic evaluation performed to detect underdialysis and dysfunctional accesses prior to thrombosis
  - Access flows
    - Measured by ultrasound dilution/conductance, dilution/thermal, dilution/Doppler
      - AVG < 600 mL/min or < 1,000 mL/min if > 25% drop → referral
      - AVF < 400 mL/min or < 1,000 mL/min if > 25% drop → referral
  - Static venous pressure
    - Useful in AVGs
      - Insensitive to detect inflow problems, which are more common in AVFs
    - Intraaccess pressure to mean arterial pressure (MAP) ratio > 0.5 triggers referral
  - Detection of recirculation
    - Occurs when Qa < Qb
      - Could be due to inflow or outflow problem
    - Recirculation > 10% triggers referral
    - Not sensitive surveillance technique AVGs
    - AVGs can thrombose with Qa < 600 mL/min
      - Recirculation occurs when flow rates are < pump rates, typically set at 350-400 mL/min
  - Doppler ultrasound
    - Can measure flow rates, detect sites of stenosis
- **DASS**
  - Arterial insufficiency ipsilateral to HD access
  - Risk factors
    - Diabetic patients with multiple prior shunts
    - Female gender
    - Brachial artery inflow
    - High-flow shunts/large anastomoses
    - Grafts (2.7-8.0%) more common than fistulas (< 2.0%)
  - Stages
    - Grade 1 (mild): Cool extremity but otherwise few symptoms
      - Distal flow augmentation with access occlusion
      - No treatment needed
    - Grade 2 (moderate): Intermittent ischemia
      - Pain during dialysis or with exercise
      - Treatment occasionally needed
    - Grade 3 (severe): Rest pain/tissue loss
      - Treatment mandatory, often with access ligation
- **National Kidney Foundation-Kidney Disease Outcomes Quality Initiative (NKF-KDOQI)**
  - Provides multidisciplinary evidence-based clinical guidelines for CKD patients
    - Includes all stages of CKD and all aspects of care
  - Vascular Access Guidelines most relevant to interventional procedures
    - Published 2006, update forthcoming January 2018

PREPROCEDURE

Indications

- Stenosis: Most frequent problem in mature access
  - Usually result of neointimal hyperplasia resulting from surgical manipulation and disruption of laminar flow
  - Decreases Qa
    - Places access at risk for thrombosis
    - Can lead to recirculation, low Kt/V
- Failure of maturation: Access does not meet rule of 6s by 6 weeks after creation
- DASS (vascular access steal syndrome)
  - Grade 2 or 3
  - Endovascular treatment preferred when arterial obstruction suspected
- Thrombosis: Hemodialysis access declotting procedures

Contraindications

- Infected access site
- Hemodynamic instability
- Contrast allergy
  - May be addressed by premedication or with use of CO_2
- Uncorrectable coagulopathy

Preprocedure Imaging

- B-mode ultrasound
  - Directly shows stenoses
  - Avoid creating false appearance of stenosis by compressing with transducer
- Pulse Doppler
  - Feeding artery
    - Normally has low-resistance waveforms
    - High-resistance waveforms consistent with access thrombosis or high-grade stenosis
  - Arterial anastomosis
    - Normal to have turbulent flow and elevated velocities

    - Peak systolic velocity > 400 cm/sec consistent with anastomotic stenosis
    - Peak systolic velocity ratio compared to feeding artery > 3 consistent with anastomotic stenosis
  - Outflow vein
    - Normally low-resistance, but pulsatile, waveforms
    - Focally elevated peak systolic velocity compared to adjacent normal vein consistent with stenosis
      - ☐ Ratio 2-3 consistent with moderate stenosis
      - ☐ Ratio > 3 consistent with severe stenosis
  - Central veins
    - Direct interrogation difficult
    - Signs of central stenosis or occlusion: Lack of atrial pulsatility, lack of flow augmentation with forced inhalation, retrograde flow in internal jugular vein

Getting Started

- Things to check
  - Examine access
    - Visual inspection
      - ☐ Arm or face swelling
      - ☐ Chest wall collaterals
    - Palpation of thrill
      - ☐ Normal thrill: Present at anastomosis, continuous
      - ☐ Inflow stenosis: Weak thrill
      - ☐ Outflow stenosis: Discontinuous thrill, focal thrill at site of stenosis removed for arterial anastomosis
    - Palpation of pulse
      - ☐ Normal: Soft pulse
      - ☐ Inflow stenosis: Weak pulse
      - ☐ Outflow stenosis: Increased pulse
  - Serum potassium level
    - Mild elevation (< 6.5) acceptable if no associated ECG findings
  - Bleeding parameters
    - Prefer platelets > 50
    - INR < 3.0 typically acceptable
  - Review of allergies
  - Review prior images/surgical reports to identify inflow and outflow vessels
- Medications
  - Contrast material
  - Local anesthetic: Lidocaine (1-2%)
  - Sedation medications
    - Fentanyl and midazolam both hepatically metabolized
      - ☐ Midazolam 1/2 life prolonged in renal failure patients
  - Heparin
    - 3,000-U bolus is typical dose if performing angioplasty with 1,000 U given if procedure extends beyond 1 hour
  - Antibiotics
    - Controversial but often given if placing stent graft
- Equipment list
  - Ultrasound
  - Micropuncture set
  - Short sheaths (5-7 Fr)
  - Guidewires
  - Angioplasty balloons
    - Size according to normal-caliber adjacent vessel diameter
      - ☐ Oversize by ~ 10-20% compared to adjacent normal vessel diameter
    - Rough guides
      - ☐ 5 mm for arterial anastomosis
      - ☐ 6-7 mm for AVG stenosis
      - ☐ 12 mm for subclavian vein
      - ☐ 14 mm for brachiocephalic vein
      - ☐ 18 mm for superior vena cava
    - High-pressure, noncompliant balloons needed
      - ☐ HD access stenosis are often obstinate
  - Stents
    - Covered stents preferred in HD access
    - Immediately available in case of vein rupture
  - Embolization coils if embolizing competing side branches
  - Suture materials
    - 2-0 Nylon suture for purse-strings sutures
  - Sterile dressing materials

PROCEDURE

Patient Position/Location

- Extremity of interest extended outward

Procedure Steps

- **Standard intervention of mature but dysfunctional AV access shunts**
- Access shunt with micropuncture set
  - Puncture toward site of suspected stenosis
  - Allow sufficient distance (> 6 cm) between puncture site and stenosis
- Perform angiogram through 5-Fr micropuncture sheath
  - Image entire access from feeding artery to right atrium to detect access stenosis
    - Occlude outflow while injecting to reflux across anastomosis into feeding artery
  - Decide if angioplasty is indicated
    - Stenosis > 50% **and** corresponding clinical signs of access dysfunction
    - Avoid indiscriminate angioplasty or angiographic stenoses without clinical significance
      - ☐ Angioplasty of asymptomatic central stenoses leads to more rapid and aggressive progression of stenosis
  - If 5-Fr catheter facing appropriate direction, place sheath
    - Place 6-Fr sheath for most interventions
    - Place 7-Fr sheath for dilating central stenoses with planned balloon diameter > 10 mm
- Administer heparin
  - Typical dose 40 U/kg or 3,000 U
  - Not given by all practitioners
  - Prevents thrombus formation during balloon-induced access flow stagnation
- Advance wire and catheter across stenosis
- If outflow stenosis, place wire into central veins
  - 0.035" Amplatz or Rosen preferred
  - Place tip into inferior vena cava to avoid wire-induced arrhythmia
- If treating inflow stenosis, place wire into feeding artery upstream from anastomosis

Inflow vs. Outflow Stenosis

Problem Detected	Inflow Stenosis	Outflow Stenosis
During cannulation	Difficulty with cannulation (lacks turgor for easy puncture)	Prolonged bleeding (> 10 min) after needle withdrawal
Findings on palpation	Weak thrill	Markedly pulsatile
Findings on auscultation	Weak bruit	Discontinuous bruit; high pitched or focal at site of stenosis
Flow rate	Decreased	Decreased
Static venous pressures	Normal or low	Increased

Objective Measures Triggering Hemodialysis Access Evaluation

Measurement	Trigger for Evaluation
Kt/V (dialysis adequacy)	Absolute value < 1.2 or decrease by 0.2 or more
Static venous pressures	> 0.5[1]
Recirculation	> 10%
Access flow rates	Absolutes: AVF < 400 mL/min, AVG < 600 mL/min Decrease by > 25% from baseline

1 = mean access pressure/mean arterial pressure.

KDOQI Vascular Access Guideline 4: Detection of Access Dysfunction: Monitoring Surveillance and Diagnostic Testing, 2016.

  - 0.018" wire allow for low-profile balloon catheter usage or 0.035" Bentson wire
  - Cannulating upstream artery may require use of tight reverse curved catheter (e.g., internal mammary catheter)
- Select appropriate angioplasty balloon
  - Diameter: ~ 10-20% > diameter of adjacent normal-caliber vessel
  - Length: Extends ~ 5 mm beyond stenosis in both directions
  - High-pressure, noncompliant balloons preferred
- Perform angioplasty
  - For tandem lesions, start with more central stenosis
  - Advance balloon over guidewire
  - Position balloon at site of stenosis using roadmap or bony landmarks
  - Use inflation device
    - Fill device with 1/3 strength contrast
    - Inflate under constant fluoroscopy until stenotic "waist" expands fully or burst pressure of balloon is met
    - Options when effacement of stenotic waist not achieved
      - Upsize balloon by 2 mm
      - Ultra high-pressure balloon (e.g., Conquest: Bard Medical Covington, GA)
      - Consider cutting balloon
      - Parallel wire technique: 0.018" wire placed adjacent to balloon catheter
    - Do not exceed manufacturer's rated balloon burst pressure
  - Maintain guidewire access during percutaneous transluminal angioplasty (PTA) and during follow-up angioplasty
    - Allows easy retreatment with suboptimal results, control in event of vessel rupture
  - Keep balloon inflated for 1-2 min
  - Perform follow-up angiogram through sheath while maintaining wire access
    - Evaluate for presence of residual stenosis or acute complications
    - Repeat physical examination to evaluate improvement in thrill or decrease in access pulsatility
  - **Stenting (covered stents preferred)**
    - Accepted indications
      - Acute elastic recoil of vein after angioplasty
      - Vessel rupture not responsive to balloon tamponade
      - Early interval restenosis (< 3 months)
    - Consider in failing AVG with venous anastomotic stenosis
      - Longer primary patency with covered stents compared to angioplasty alone in prospective randomized controlled trial
    - Avoid stent placement at thoracic inlet
      - Can be crushed by clavicle and 1st rib
    - Avoid placing across inflow vessels (e.g., internal jugular vein or contralateral brachiocephalic vein)
      - Precludes using these vessels for subsequent vascular access
- **Remove sheath and achieve hemostasis**
  - Purse-string suture
    - Take 3-4 bites of subcutaneous tissue with 2-0 monofilament sutures
      - Triangle or square shape
      - Depth of bites into perigraft/perivascular tissue but not into access
    - Place 1-cm piece of tubing between 2 ends of suture

      - Cut portion inner dilator of vascular sheath can be used
      - Can be subsequently twisted to tighten knot and decrease bleeding
      - Allows for ease of removal allowing passage of scissors under knot
    - Make surgeon's knot with 2 ends of suture
      - Ensures knot will slide down to skin (no air knot)
    - Tighten suture while pulling vascular sheath
      - Increased lateral tension on suture if persistent bleeding
    - Lock suture
    - Apply sterile dressing
    - Remove suture after 1 hour or at next dialysis session
      - Do not leave for > 2-3 days
  - Woggle suture
    - Similar initial steps to purse-string suture
      - Encircle sheath with 2-0 monofilament suture
    - Feed free ends of suture into flow switch, 3-way stop-cock or Slip-Not Suture Retention Device (Merit Medical)
    - Remove sheath while sliding flow switch, 3-way or Slip-Not down over puncture site
    - Lock device in place
    - When removing, slightly loosen device, check for adequate hemostasis before cutting and removing suture
  - Manual compression
    - Digital pressure over access site
      - Do not occlude access
    - Time to achieve hemostasis is variable (10 min to 1 hour)
      - Dependent on sheath size, use of anticoagulants
- **Percutaneous treatment of fistulas, which have failed to mature**
  - **Access stenosis**
    - Obtain access with 5-Fr sheath
      - **Inflow stenosis**: Obtain retrograde access
      - Cross anastomosis and place wire into feeding artery
      - If difficulty encountered, brachial artery puncture and 3-Fr catheter placement with diagnostic angiogram or wire advancement and snaring can be helpful
      - **Outflow stenosis**: Obtain antegrade access
      - Place wire centrally
    - Choose appropriate-sized balloon based on adjacent vessel diameter
    - Guidelines
      - Anastomosis: 3- to 4-mm balloon
      - Juxtaanastomotic segment: 4- to 5-mm balloon
    - Conclude procedure
      - Remove wires, catheters, and sheaths
      - Manual pressure needed
      - Immature fistulas have insufficient perigraft/perifistula fibrotic soft tissue incorporation for pursestring closure to work
    - Follow-up and repeat dilation in 2 weeks
      - Upsize balloon by 1-2 mm
  - **Accessory veins**
    - Superficial veins: Percutaneous ligation
      - Perform angiogram to identify target accessory vein
      - Identify same target vein with ultrasound
      - Ligate 5 mm from origin from fistula to prevent inflammatory changes from involving fistula causing delayed stenosis
      - Make small skin incisions on either side of target vein
      - Pass blunt-tipped needle deep to target vein under ultrasound guidance
      - Remove inner stylet of needle
      - Pass suture through needle (0-0 or 2-0 Silk)
      - Retract needle, keeping suture in place
      - Pass blunt-tipped needle superficial to vein under ultrasound guidance
      - Remove inner stylet, pass suture through needle
      - Tie surgeon's knot, tighten, but do not lock
      - Repeat angiogram, confirm occlusion of desired target
      - Lock suture, bury knot under skin
    - Deep veins: Coil embolization
      - Cannulate accessory vein with 5-Fr catheter and Glidewire
      - Confirm deep location by performing ultrasound and angiogram in 2 different projections
      - Choose appropriate coil; 2 mm larger than target vessel to prevent central embolization
      - Place coil > 5 mm from origin of fistula
      - Repeat angiogram to ensure targeted vessel occlusion
  - Remove sheath and apply manual pressure
    - Pursestring or Woggle sutures not effective in immature fistulas
      - Lack necessary soft tissue incorporation
- **Endovascular treatment of DASS**
  - Balloon dilation &/or stenting of arterial obstruction
    - e.g., proximal subclavian artery occlusion or stenosis
  - Minimally invasive limited ligation (MILLER procedure)
    - Used for grade 2 DASS
    - Undersized angioplasty balloon placed in juxtaanastomotic segment
    - Sutures tied tightly around angioplasty balloon
    - Analogous to surgical fistula plication with subsequent ePTFE banding
  - Embolization of distal radial artery (for RC AVFs only)
    - DASS in RC fistulas caused by excessive shunting from ulnar artery through palmar arch with retrograde through distal radial artery and into fistula
      - This flow can be occluded with coil embolization of radial artery distal to AVF or via surgical ligation
  - Embolization of accessory outflow branches
    - Increases flow resistance
      - Increases downstream arterial flow
      - No negative impact on access flow rates
    - Can also be done by surgical ligation

Findings and Reporting

- Document reasons for initial referral, baseline physical examination

- Describe initial angiographic findings from inflow artery to right atrium
- Describe all interventions
  - Balloon diameter, length, and make
  - Coil diameter, length, and make
  - Stent diameter, length, and make
- Describe complications and treatment
- Describe postintervention angiogram
- Document postintervention physical examination

Alternative Procedures/Therapies

- Surgical
  - **Juxtaanastomotic stenosis**
    - Proximalization of the anastomosis
      - ☐ Disadvantages: Can redevelop stenosis of new juxtaanastomotic segment, need new maturation period (6 weeks), decreases usable length of fistula
  - **Cephalic arch stenosis**
    - Intentional flow reduction
    - Cephalic vein turn-down to more proximal basilic vein
  - **Recalcitrant, rapidly recurrent stenosis**
    - Interposition graft
      - ☐ Useful in puncture zone where stent placement is not advised
      - ☐ Often requires use of tunneled catheter for 2 weeks after surgical revision
    - Access abandonment and creation of new access
  - **Accessory veins**
    - Surgical ligation
- **Steal syndrome: Dialysis associated**
  - Brachial artery inflow fistulas
    - Revision using distal inflow
      - ☐ Moves anastomosis from brachial artery to proximal radial or ulnar artery using vein segment
    - Distal revascularization ± interval ligation
      - ☐ Proximal to distal brachial artery bypass using vein segment (reversed saphenous vein graft) to divert flow to distal vessels
      - ☐ Adjunctive interval ligation distal to AV anastomosis can be done to prevent retrograde flow into fistula
    - Proximalization of arterial inflow
      - ☐ Ligation of existing brachial artery anastomosis
      - ☐ Connect axillary artery inflow to fistula using synthetic graft
    - Plication with banding
  - Radial artery inflow fistulas
    - Surgical ligation of radial artery distal to AV anastomosis
  - Access ligation: For severe DASS

POST PROCEDURE

Things to Avoid

- Avoid prolonged external compression on AV shunt
  - May cause access thrombosis
- Stent placement at puncture sites
- Treatment of asymptomatic central stenoses
  - Causes more aggressive and faster stenosis compared to watchful waiting

OUTCOMES

Complications

- Most feared complication(s)
  - **Vessel rupture**
    - Treat with low-pressure (2-3 atm) balloon tamponade across stenosis
      - ☐ Keep inflated for 3-5 min
      - ☐ Repeat up to 3x for persistent extravasation
    - Can place stent across rupture if above maneuver fails to work
      - ☐ Covered stent preferred, but bare stents can also be efficacious
    - Rupture rate high (~ 10%) at cephalic arch
    - Superior vena cava rupture may result in tamponade
      - ☐ Prompt recognition and treatment needed to prevent death
  - **Stent migration**
    - Oversizing stent by ~ 20%, using stent ≥ 5 cm in length mitigates risk of migration
      - ☐ If migrated, can consider trapping with larger stent or snaring stent

Expected Outcomes

- Access site stenosis
  - General access stenosis: 50-75% primary patency at 6 months
  - Cephalic arch stenosis: 42% primary patency at 6 months
  - Proximal swing segment of brachial artery to transposed basilic vein fistula: 42% primary patency at 1 year
  - AVG venous anastomotic stenosis
    - Balloon angioplasty: 78% restenosis at 6 months
    - Stent graft placement: 28% restenosis at 6 months
- Percutaneous salvage of immature fistulas
  - Overall salvage rate 75-95%
  - Multiple interventions required
    - 1 year primary patency ~ 30%

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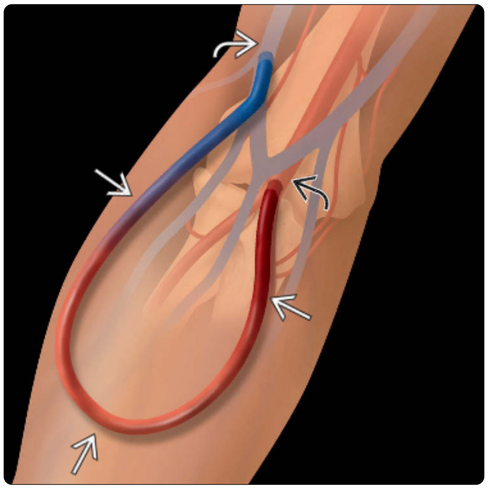
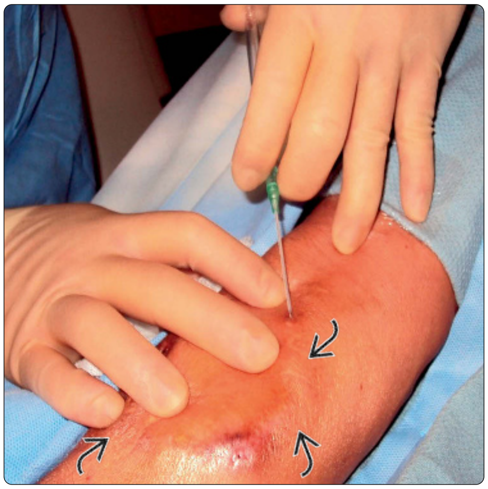
Step-By-Step: AVG Evaluation and Treatment (Anatomy of Loop Graft)

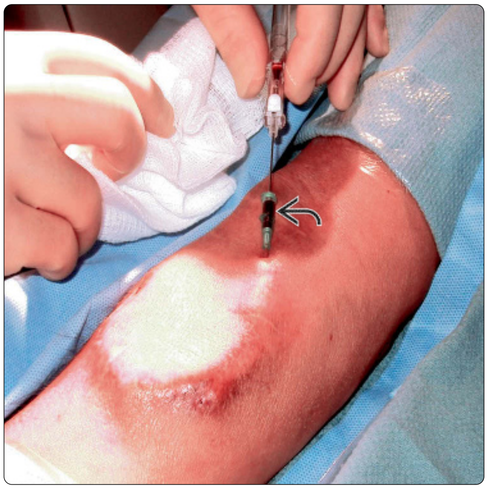


Step-By-Step: AVG Evaluation and Treatment (Accessing Loop Graft)

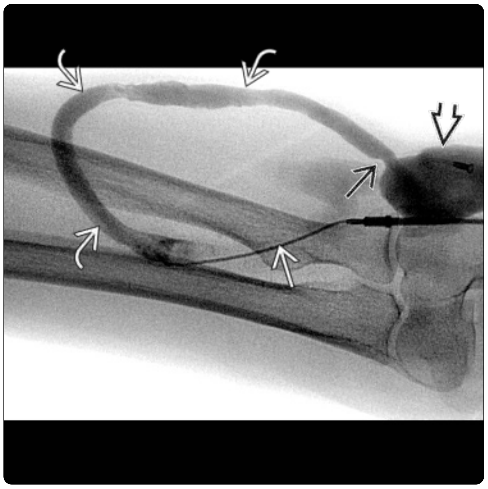


(Left) *Graphic shows the typical anatomy of a forearm hemodialysis (HD) loop graft, which is the most common location for this access. Polytetrafluoroethylene (PTFE) is used to create a prosthetic conduit* ➡ *between the artery* ↷ *and vein* ↷*. Typically an AV graft has poorer long-term patency than a fistula.* **(Right)** *To access the arterial limb of an AV loop graft* ↷*, the conduit is palpated, and an angiocatheter/microcatheter is introduced, directed toward the venous outflow.*

Step-By-Step: AVG Evaluation and Treatment (Accessing Loop Graft)

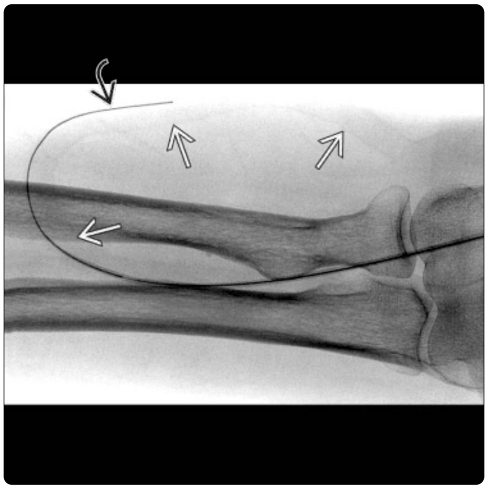


Step-By-Step: AVG Evaluation and Treatment (Contrast Evaluation of Graft)

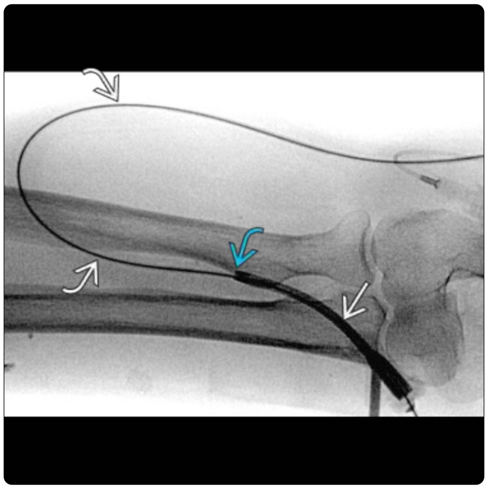


(Left) *Blood return* ↷ *signals successful AVG cannulation with the catheter. Some proceduralists use ultrasound-guidance during access of deep or potentially thrombosed grafts and fistula.* **(Right)** *A Graftogram obtained via the micro/venoclysis catheter* ➡ *shows contrast filling the prosthetic conduit loop* ➡ *of the graft. Mild stenosis* ⇨ *at the venous anastomosis and an adjacent venous aneurysm* ⇒ *is present. Additional imaging of the venous outflow can also be obtained through this catheter.*

Step-By-Step: AVG Evaluation and Treatment (Guidewire Introduction)



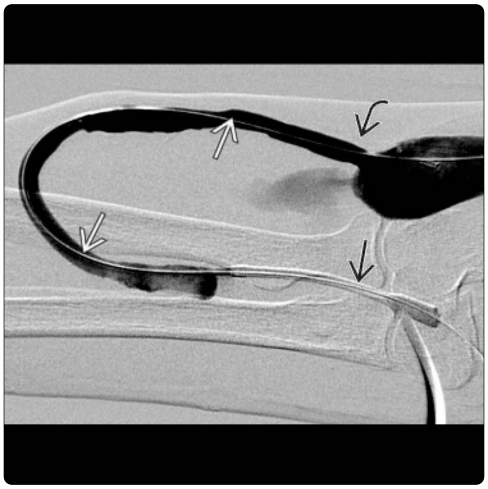
Step-By-Step: AVG Evaluation and Treatment (Access Sheath Placement)



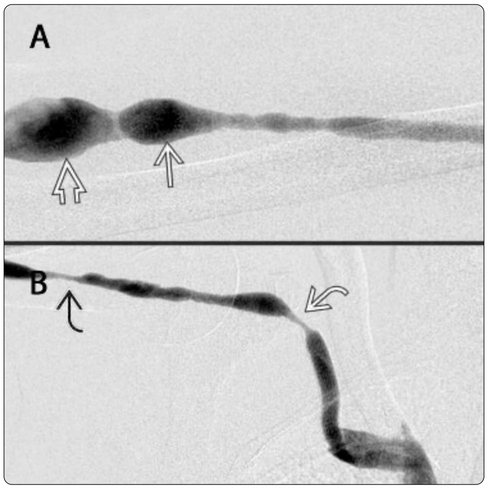
(Left) *A guidewire* ↷ *has been introduced via the angiocatheter and has been advanced into the venous limb of the graft. The prosthetic conduit* ➡ *is faintly visible. The guidewire facilitates placement of a vascular access sheath, which can then be used to introduce any catheters that may be needed for intervention.* **(Right)** *A vascular access sheath* ➡ *has been introduced over the guidewire* ➡ *and is positioned with the tip* ↷ *in the conduit, beyond the arterial anastomosis.*

(Left) *DSA obtained while injecting contrast via the access sheath → evaluates the graft and venous anastomosis ↪. A guidewire ➔ is in place. After evaluating the venous anastomosis, the venous outflow, central veins, and SVC should be imaged.* **(Right)** *DSA of the AVG venous outflow (A) shows that the venous aneurysm ➡ is bilobed with a 2nd aneurysm ➔ seen. (B) More centrally, there is a severe cephalic vein stenosis ↪ as well as a 2nd stenosis ⤷ within a previously placed covered stent in the cephalic arch.*

Step-By-Step: AVG Evaluation and Treatment (DSA Loop Graftogram)

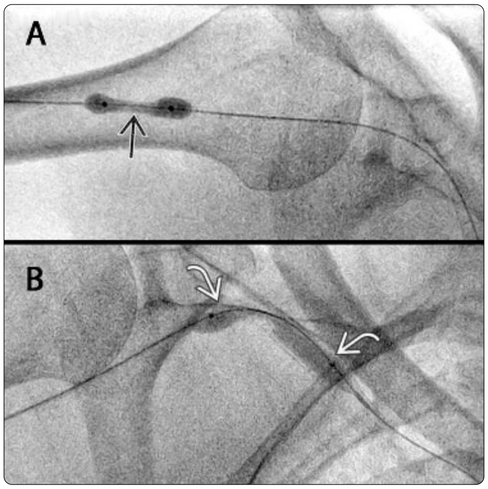


Step-By-Step: AVG Evaluation and Treatment (DSA of Venous Outflow)

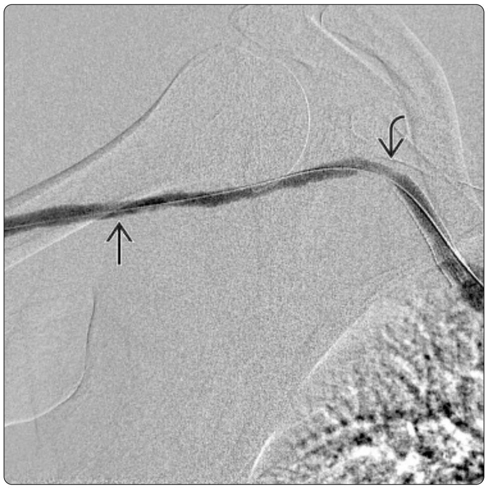


(Left) *(A) A partially inflated PTA balloon with a narrowed waist → reflects the previously seen severe cephalic vein stenosis. When the balloon was brought to nominal pressure, the stenosis was eliminated. (B) A larger caliber balloon ⤷ dilated the stenosis in the covered stent at the cephalic arch.* **(Right)** *DSA venogram of the cephalic vein after angioplasty shows marked caliber improvement in the vein → overlying the proximal humerus and moderate improvement in the cephalic arch ↪ adjacent to the covered stent.*

Step-By-Step: AVG Evaluation and Treatment (Angioplasty of Stenoses)

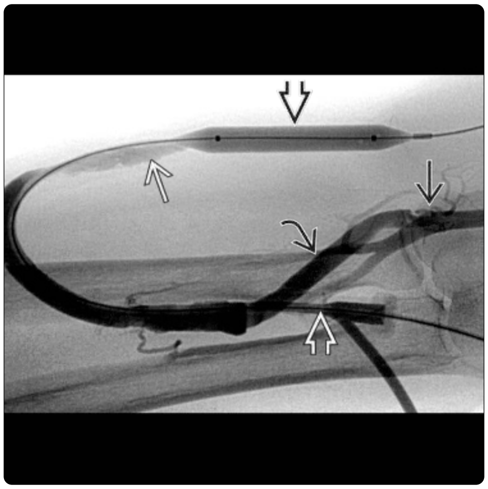


Step-By-Step: AVG Evaluation and Treatment (Postangioplasty DSA)

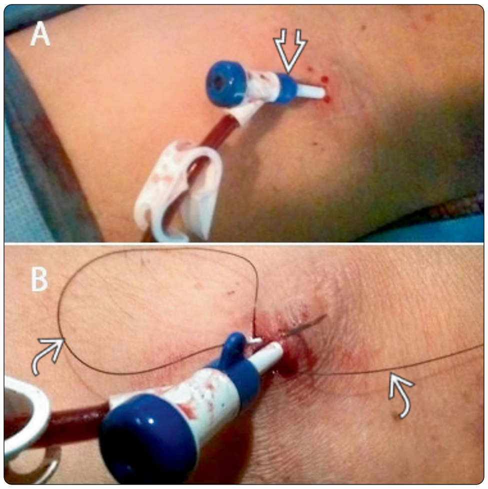


(Left) *It is important to evaluate the arterial anastomosis. This is facilitated by occluding venous outflow while injecting contrast. A PTA balloon ⇨ is inflated in the venous limb ➔ of the graft while contrast injected via the sheath ➡ refluxes into the graft ↪ and across the arterial anastomosis →.* **(Right)** *(A) The vascular access sheath ➡ must now be removed. (B) Nylon 3-0 suture ⤷ is used to form a purse-string encircling the sheath. As the sheath is removed, the suture is tightened, achieving hemostasis.*

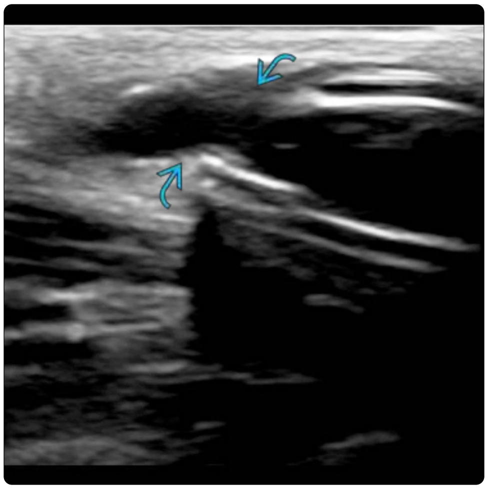
Step-By-Step: AVG Evaluation and Treatment (Arterial Anastomosis)



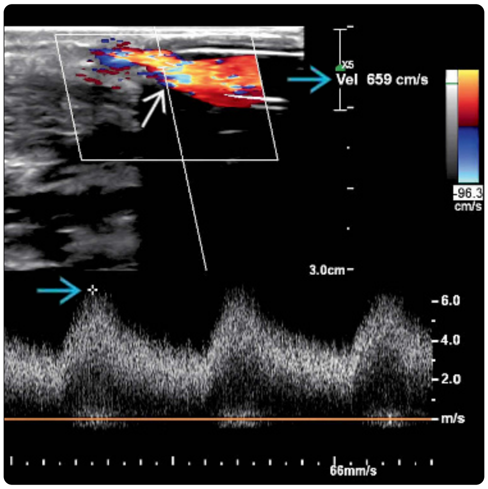
Step-By-Step: AVG Evaluation and Treatment (Purse-String Suture)



AVG: Venous Anastomotic Rupture (Initial Ultrasound)

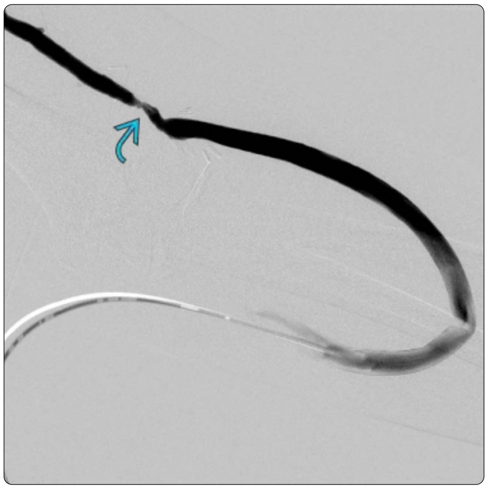


AVG: Venous Anastomotic Rupture (Color Doppler Ultrasound)

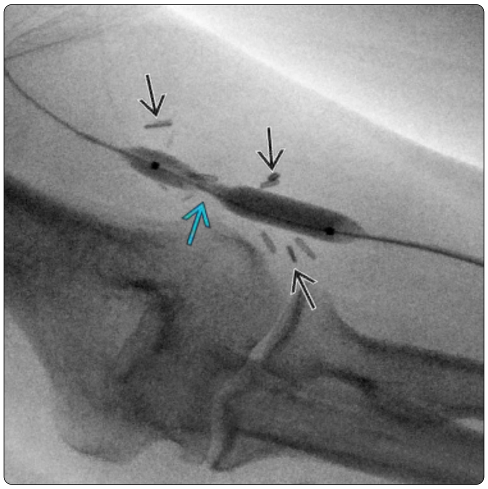


(Left) *B-Mode ultrasound shows moderate narrowing at the graft venous anastomosis ⇨, which extends just downstream from venous anastomosis. This patient was referred for ultrasound and then intervention because of low Kt/V.* **(Right)** *Color Doppler Ultrasound in this area shows aliasing ➔ and markedly elevated flow velocity ⇨, which was > 3x that of the rest of the graft, consistent with a severe stenosis.*

AVG: Venous Anastomotic Rupture (Initial Angiogram)

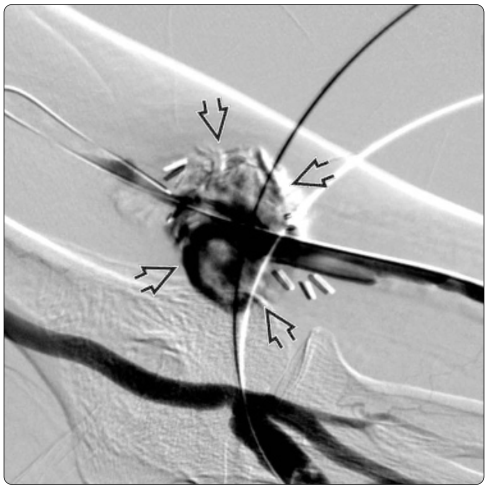


AVG: Venous Anastomotic Rupture (Stenosis-Angioplasty)

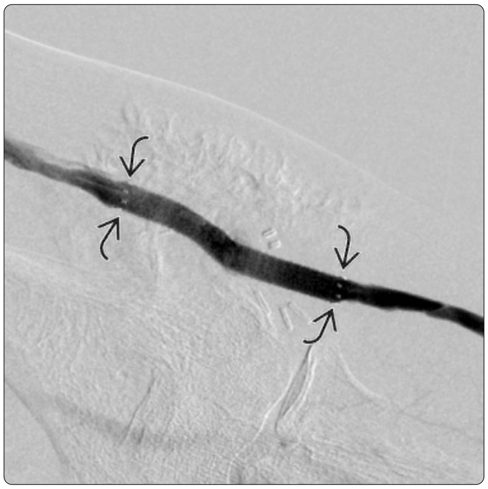


(Left) *The graft was accessed in the arterial limb pointing toward the venous anastomosis. Initial injection confirmed the suspicion of narrowing just downstream from the graft to vein anastomosis ⇨.* **(Right)** *A 7-mm balloon was used to dilate the graft to vein anastomotic stenosis. Note the waist ⇨. Multiple surgical staples ⇨ are present at the region of the anastomosis. High-pressure inflation was necessary to fully dilate the balloon/stenosis.*

AVG: Venous Anastomotic Rupture (Stenosis-Extravasation)



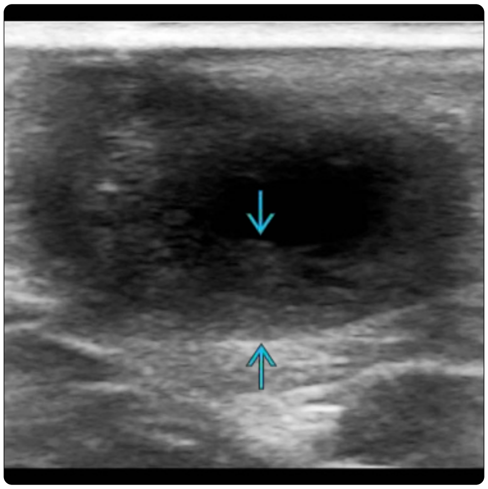
AVG: Venous Anastomotic Rupture (Covered Stent Repair)



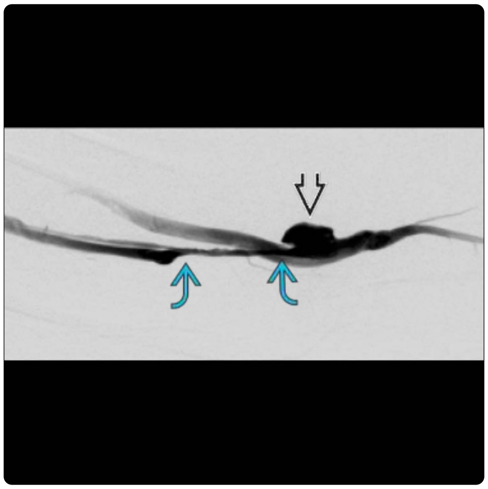
(Left) *After angioplasty, a repeat angiogram was done showing rupture of the anastomosis with extravasation of contrast ⇨. A balloon was placed across the site of extravasation and inflated to 3 atm of pressure. Risk factors for anastomotic disruption include a recently created access (< 1 month) or inappropriate balloon oversizing.* **(Right)** *A 7-mm stent graft ⇨ (Gore Viabahn) was deployed and post dilated with a 7-mm balloon. Extravasation ceased and no residual stenosis is present.*

(Left) *This patient presented for evaluation because of low flows during dialysis. The initial ultrasound revealed a relatively long-segment stenosis of the juxtaanastomotic region caused by exuberant venous neointimal hyperplasia* → *.* **(Right)** *Physical examination revealed hyperpulsatility at the AV anastomosis* ⇨*. A fistulogram obtained via retrograde access shows the long segment juxta-anastomotic narrowing* ↷*.*

AVF: Juxtaanastomotic Neointimal Hyperplasia (Ultrasound)

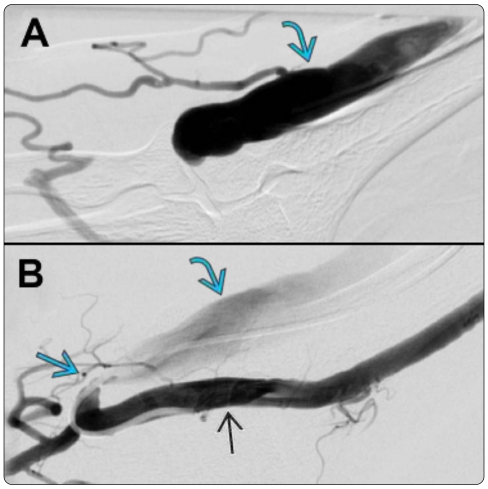


AVF: Juxtaanastomotic Neointimal Hyperplasia (Fistulogram)

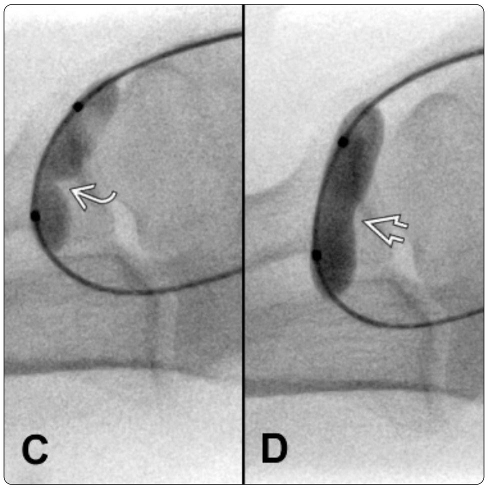


(Left) *An initial fistulagram while occluding the venous outflow (A) failed to opacify the feeding artery, suggesting inflow stenosis. A 4-Fr catheter was advanced retrograde through the fistula into the upstream brachial artery* ⇨*. Focal juxtaanastomotic stenosis* → *was found. The 4-Fr catheter was nearly occlusive at this site, and there was only faint opacification of the fistula* ↷*.* **(Right)** *Balloon dilation with a 7-mm diameter, 2-cm long cutting balloon was done. The initial waist* ➡ *(C) was successfully effaced* ➡ *(D).*

AVF: Cutting Balloon Angioplasty of Juxtaanastomotic Stenosis (Initial Images)

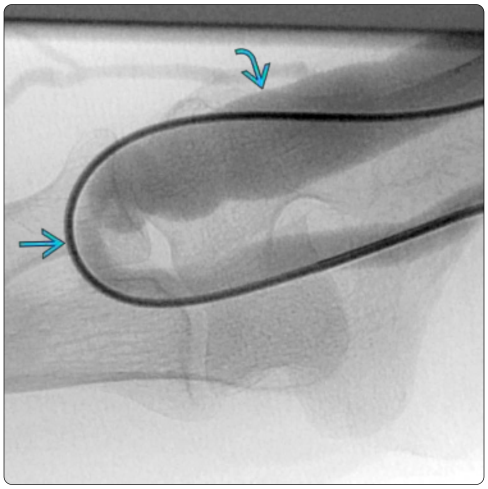


AVF: Cutting Balloon Angioplasty of Juxtaanastomotic Stenosis (Angioplasty)

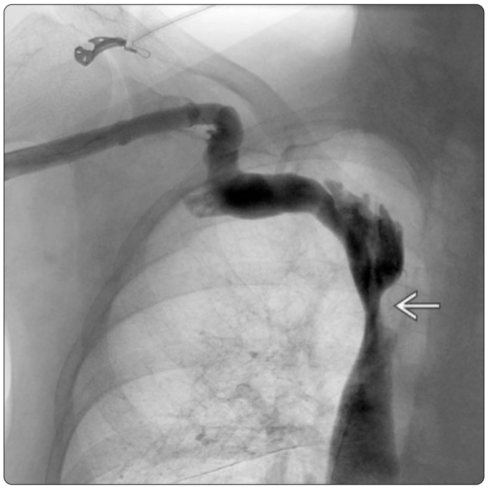


(Left) *A follow-up angiogram shows brisk flow in the fistula* ↷ *with marked improvement in luminal diameter of the juxtaanastomotic segment* →*. Blood now flows preferentially into the fistula, whereas previously it was toward the hand.* **(Right)** *A central venogram showed > 50% stenosis* ➡ *of the SVC. This patient was not symptomatic, and therefore this was not dilated as this can cause more rapid stenosis progression than watchful waiting. Intervention should only be performed in symptomatic patients.*

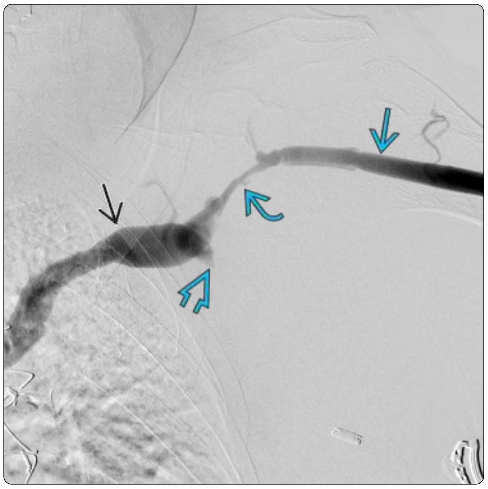
AVF: Cutting Balloon Angioplasty of Juxtaanastomotic Stenosis (Postangioplasty)



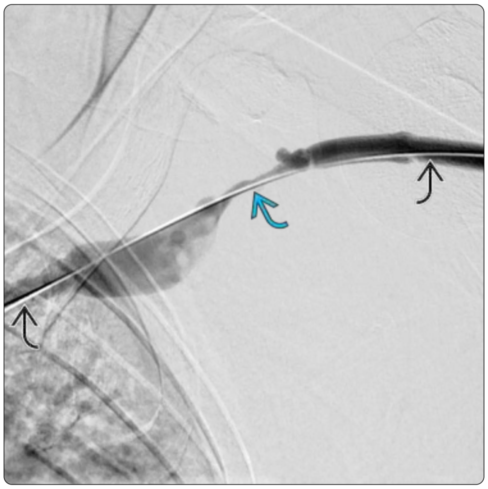
AVF: Cutting Balloon Angioplasty of Juxtaanastomotic Stenosis (Central Venogram)



Outflow Stenosis: Cephalic Arch (Initial Images)

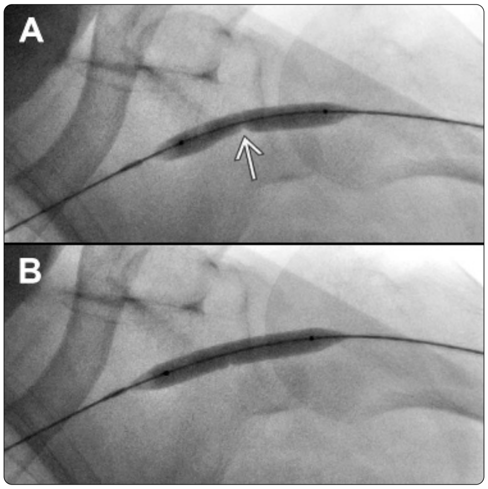


Outflow Stenosis: Cephalic Arch (Stenosis Crossed With Wire)

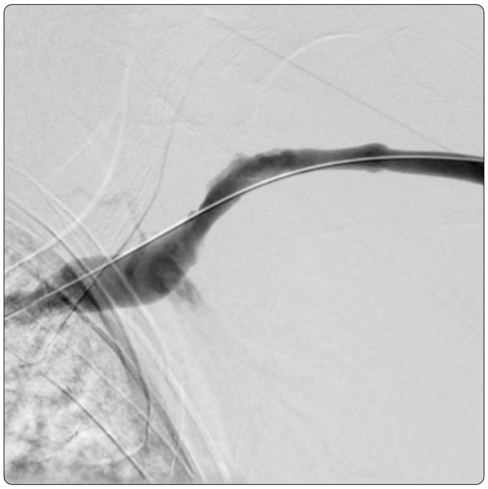


(Left) *A 55 year old with ESRD dialyzed through a left upper arm brachiocephalic fistula, referred for fistulogram because of prolonged bleeding after dialysis, is shown. Initial fistulogram shows moderate to severe stenosis of the cephalic arch* ↷*, which is the central-most portion of the cephalic vein* →*. The cephalic arch joins the axillary vein* ⇨ *to become the subclavian vein* →*.* **(Right)** *Using a directional catheter and a wire, the stenosis* ↷ *was crossed. An 0.035" Amplatz wire* ↷ *was placed with tip in the inferior vena cava.*

Outflow Stenosis: Cephalic Arch (Balloon Dilation)

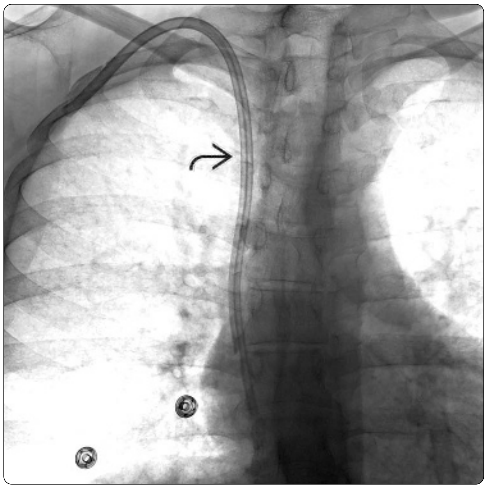


Outflow Stenosis: Cephalic Arch (Angiogram After Dilation)

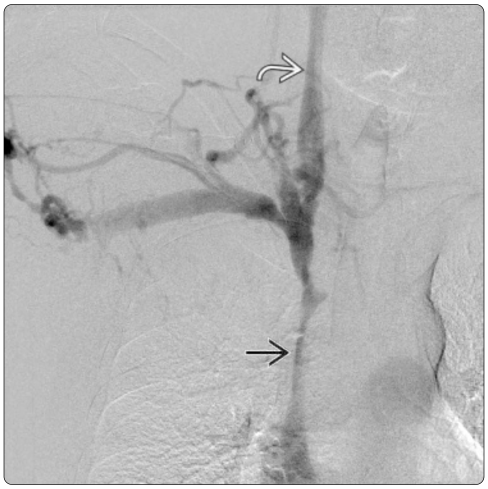


(Left) *After 3000 U of heparin was given, a 9-mm high-pressure (Conquest Bard PV) balloon was used to dilate this stenosis. Note the initial waist* ➡*, which was eradicated only with insufflation above 20 atm. The balloon was kept inflated for 90 seconds.* **(Right)** *Postdilation angiogram shows near normal caliber of the cephalic arch. Dialysis access stenoses in general and cephalic arch stenoses in particular often require high-pressure balloons for adequate dilation.*

SVC Stenosis: HD Catheter Induced (Catheter Intact)



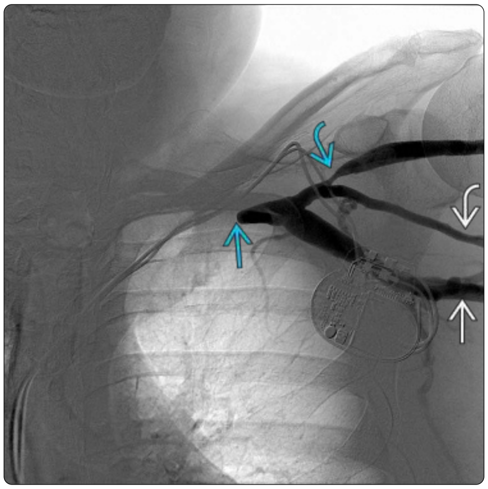
SVC Stenosis: HD Catheter Induced (Venogram After Catheter Removal)



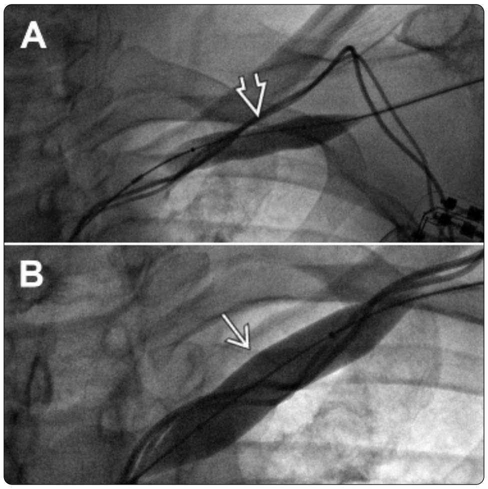
(Left) *Central venous catheters are a major cause of central venous stenosis. Nearly 80% of patients initiate dialysis via a catheter, with central venous stenosis occurring in up to 50% of these patients. Note this right internal jugular vein central venous catheter* ↷*.* **(Right)** *A right upper arm AVG was placed and the catheter removed. However, the patient had recurrent arm swelling and prolonged bleeding at HD. SVC stenosis* → *(and retrograde internal jugular flow* ↷*) had occurred as a result of the catheter.*

(Left) *This patient presenting with painful left arm swelling dialyzes through a left upper arm brachiocephalic fistula. He also has a left-sided pacemaker. An initial fistulogram shows complete occlusion of the subclavian vein* ⇨ *with retrograde flow via the axillary* ➡ *and a large collateral vein* ➦. *Note also moderate cephalic arch stenosis* ↪. **(Right)** *After crossing the central occlusion, 10-mm* ➡ *(A) followed by 14-mm* ➡ *(B) balloon dilations were performed keeping the balloons inflated for 3 minutes.*

Central Occlusion: Pacemaker Wire Induced (Initial Images)

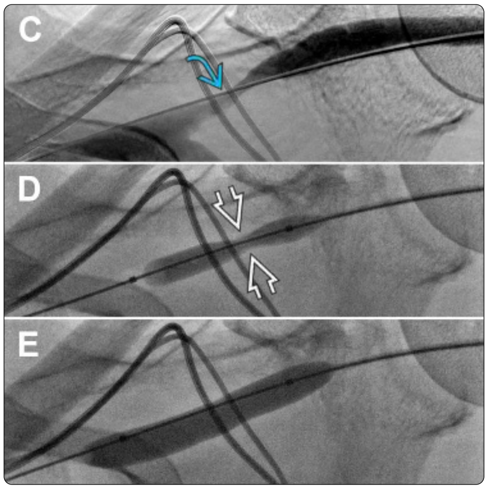


Central Occlusion: Pacemaker Wire Induced (Angioplasty)

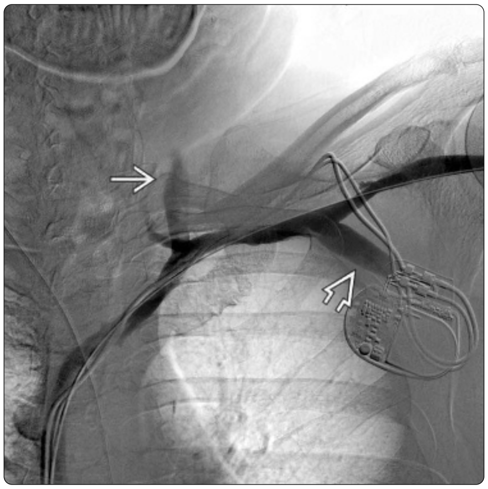


(Left) *An additional moderate cephalic arch stenosis was present* ↪ *(C) and subsequently angioplastied with an 8-mm balloon. Note the waist* ➡ *present during inflation (D), which is eradicated only at high pressures (E).* **(Right)** *A final angiogram after subclavian vein recanalization and angioplasty as well as cephalic arch angioplasty shows marked interval improvement in flow. Some central stenosis likely persists, which is belied by the retrograde flow up the left internal jugular vein* ➡ *and down the axillary vein* ➡.

Central Occlusion: Pacemaker Wire Induced (Additional Cephalic Arch Stenosis)

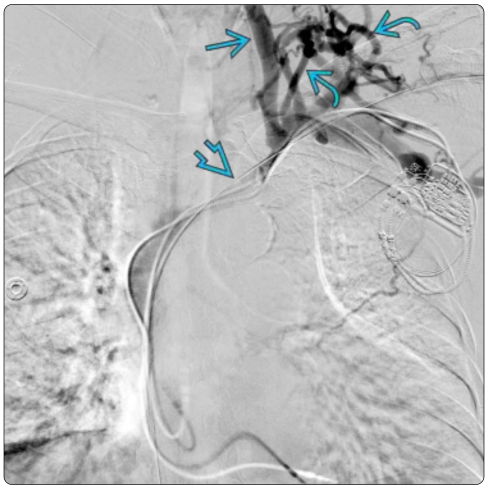


Central Occlusion: Pacemaker Wire Induced (Final Angiogram)

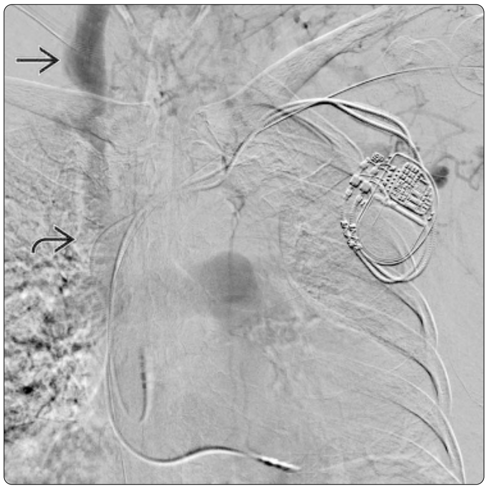


(Left) *A patient has a left upper extremity graft and ipsilateral pacemaker. She presented with arm swelling and intermittent headaches. Severe brachiocephalic vein* ⇨ *stenosis is present. The image shows multiple collateral veins* ↪, *with retrograde flow up the left internal jugular vein* ⇨. **(Right)** *A later image showed drainage via the contralateral internal jugular vein* ⇨ *to the SVC* ↪. *Cases have been reported of intracranial hemorrhage in dialysis patients from venous hypertension in the setting of central vein stenosis.*

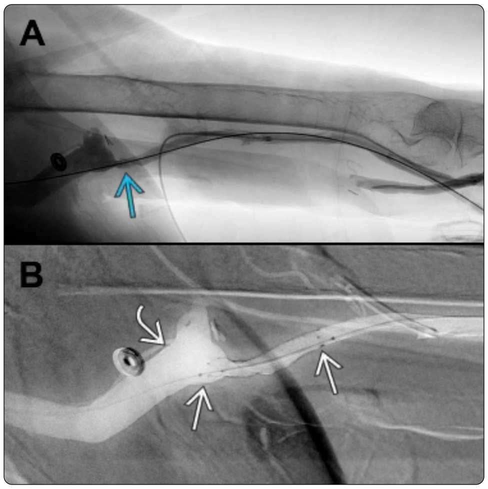
Brachiocephalic Vein Stenosis: Pacemaker Induced (Early Venous Image)



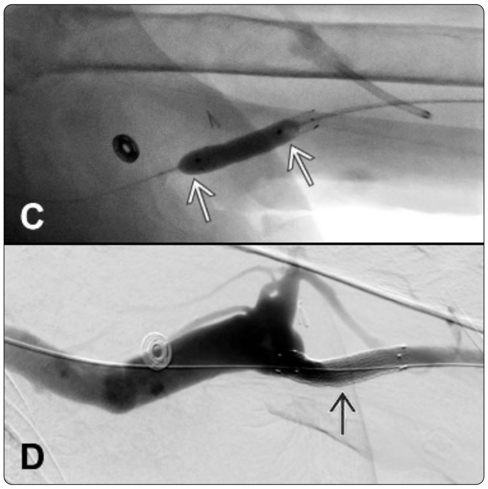
Brachiocephalic Vein Stenosis: Pacemaker Induced (Late Venous Image)



Stent Placement: Straight AVG (Venous Anastomotic Stenosis)

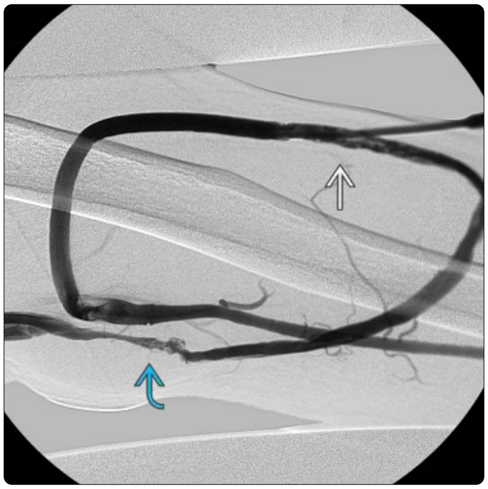


Stent Placement: Straight AVG (Patent Venous Anastomosis)

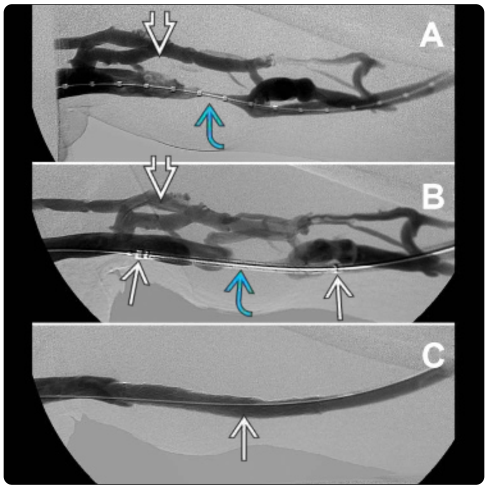


(Left) *This patient complained of prolonged bleeding after hemodialysis. An initial angiogram (A) shows stenosis at the graft venous anastomosis* ⇨*. (B) Using road map as a guide, a 7-mm Gore Viabahn* ➡ *was placed at the site of stenosis, flaring out slightly into the normal axillary vein* ➡*.* **(Right)** *Post deployment angioplasty was done with a 7-mm balloon* ➡ *(C). A final angiogram (D) shows brisk flow through the stent* ⇨ *with no residual narrowing.*

Stent Placement: Loop AVG (Venous Anastomotic Stenosis)

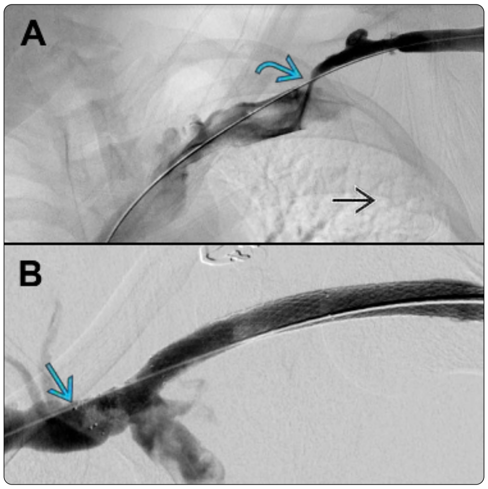


Stent Placement: Loop AVG (Patent Venous Anastomosis)

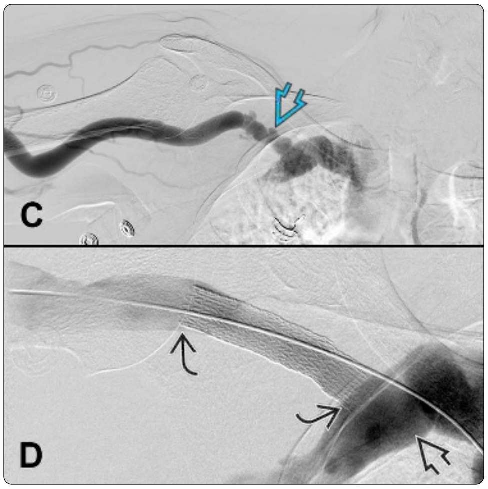


(Left) *This patient presented with AVG thrombosis. Note some residual thrombus at the apex of the graft* ➡*. Moderate to severe narrowing at the graft to vein anastomosis* ⇨ *was the inciting lesion.* **(Right)** *The decision was made to place a stent. A DSA highlights the stenosis* ⇨ *and multiple collaterals veins* ➡ *(A). The stent* ➡ *was positioned and DSA repeated prior to deployment (B). Stent was deployed and postdeployment angioplasty was done showing good flow with resolution of the collateral veins (C).*

Stent Placement: Cephalic Arch Stenosis (Malpositioned Stent)



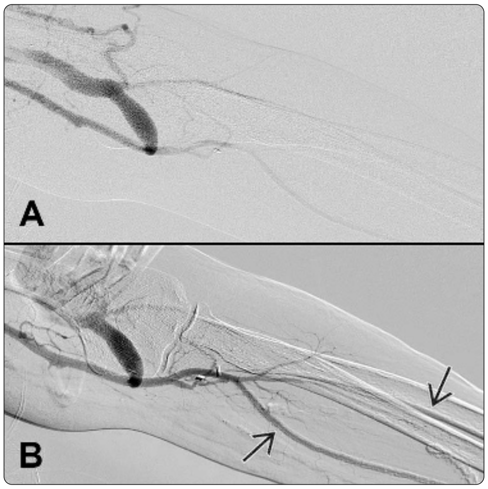
Stent Placement: Cephalic Arch Stenosis (Correctly Positioned Stent)



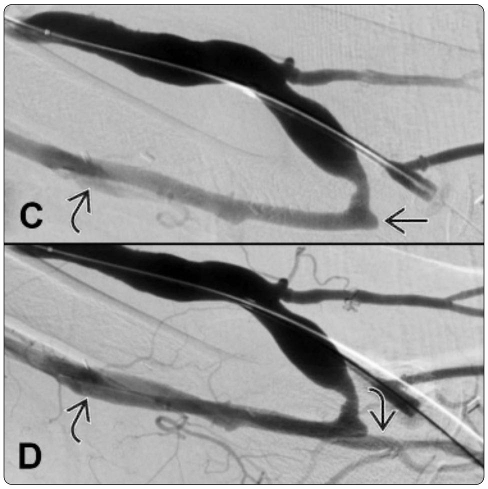
(Left) *Severe elastic recoil is present in the cephalic arch* ⇨ *after angioplasty* ⇨ *(A). This was treated with stenting, which extended too far, into the subclavian vein* ⇨ *(B). This access subsequently failed due to subclavian vein stenosis, and a thigh graft was necessary.* **(Right)** *This patient had recurrent cephalic arch stenosis. Initial angiogram shows irregular narrowing of the cephalic arch* ⇨ *(C). A stent* ⇨ *was placed extending up to the subclavian vein* ⇨*, preserving the possibility of future basilic vein access (D).*

(Left) *This patient presented with worsening hand pain and ischemic finger ulcers. Angiogram did not show correctable inflow stenosis. Angiograms were done without (A) and with (B) compression of the fistula. With compression, marked improved flow toward the hand was present* ⇨. **(Right)** *The patient underwent DRIL. Fistulagram shows ligation of the brachial artery* ⇨ *just distal to the AV anastomosis (C). Refluxed contrast opacifies, the vein graft bypass* ↪, *which supplies blood to the hand(D).*

Steal Syndrome: Distal Revascularization and Interval Ligation (Pre DRIL)

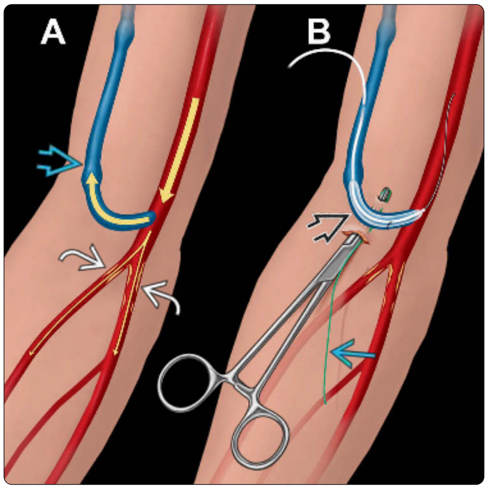


Steal Syndrome: Distal Revascularization and Interval Ligation (Post DRIL)

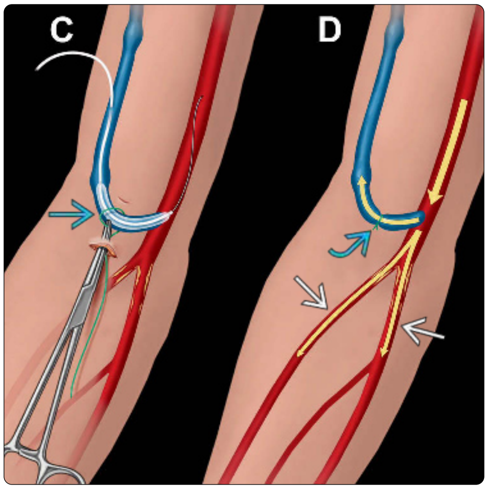


(Left) *(A) Graphic of minimally invasive limited ligation (MILLER) procedure for steal syndrome shows referential flow* ⇨ *across the AV anastomosis and minimal flow distally* ↪. *(B) A 4- or 5-mm PTA balloon* ⇨ *is inflated in the vein just distal to the anastomosis. A hemostat is used to tunnel the suture* ⇨ *beneath the vein.* **(Right)** *(C) The suture* ⇨ *is now tied tightly around the balloon. (D) A focal narrowing* ↪ *has now been intentionally created. This redirects flow distally toward the hand* ➡.

Steal Syndrome: MILLER Procedure (Graphic 1)

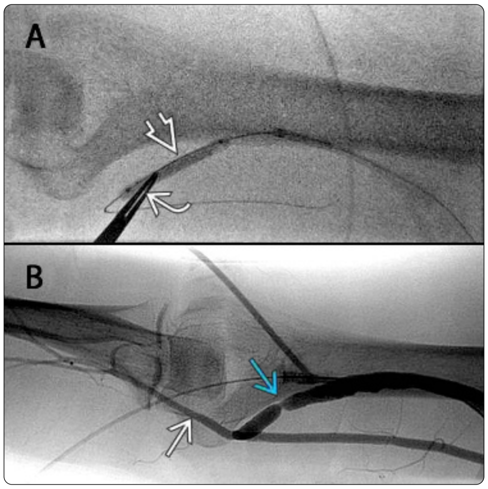


Steal Syndrome: MILLER Procedure (Graphic 2)

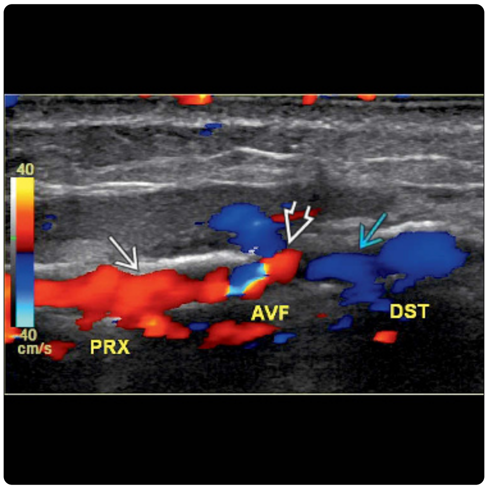


(Left) *(A) Image during the MILLER procedure shows an inflated PTA balloon* ➡ *and a hemostat* ↪ *used for tunneling the suture. (B) A waist* ⇨ *is seen in the vein, and there is improved distal arterial flow* ➡ *after the procedure.* **(Right)** *There is antegrade flow* ➡ *in the radial artery proximal to the anastomosis* ➡ *and retrograde flow distal to the anastomosis* ⇨. *Blood is stolen via the palmar arch. This type of steal may be treated by coil embolization or surgical ligation of the distal radial artery.*

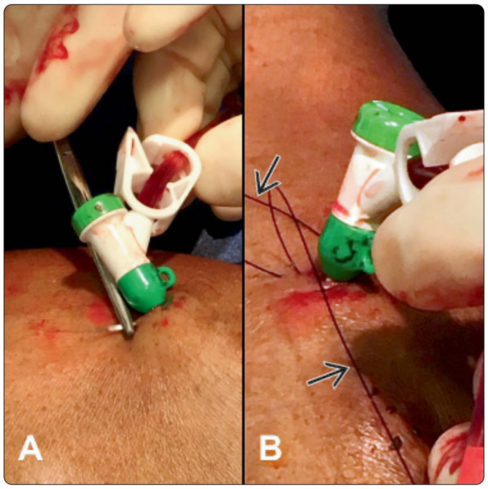
Steal Syndrome: MILLER Procedure (Angiogram)



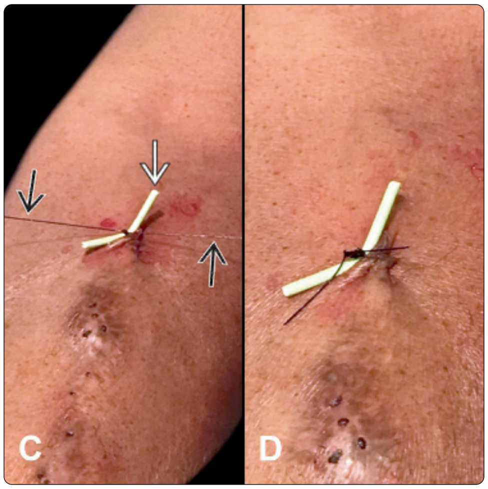
Steal Syndrome: Radiocephalic AVF (Color Doppler Ultrasound)



Purse-String Suture Placement

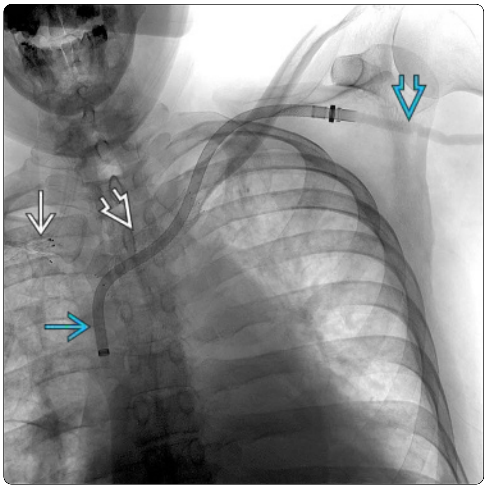


Purse-String Suture Placement

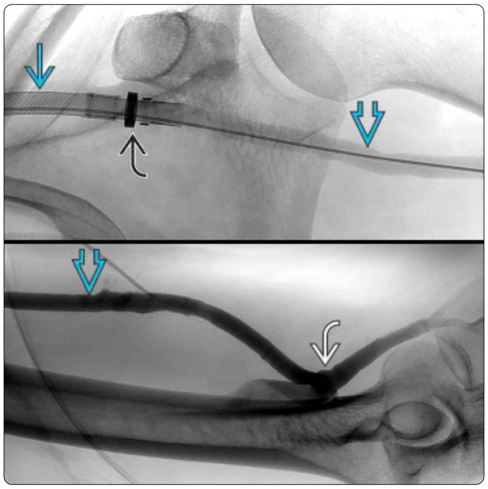


(Left) *One way to achieve hemostasis at the conclusion of a dialysis intervention on a mature access is to place a pursestring suture. Three to 4 throws are made with 2-0 Nylon suture → in a triangular or square shape (A and B).* **(Right)** *After the sutures are placed, a small plastic tube ➡, typically a cut vascular dilator, can be placed between the 2 loose suture ends →. The sutures are then tied by 1st placing a surgeon's knot (A), followed by 3-4 locking ties (D). If oozing occurs, the knot can be tightened by twisting the dilator.*

HeRO (Hemodialysis Reliable Outflow) Graft

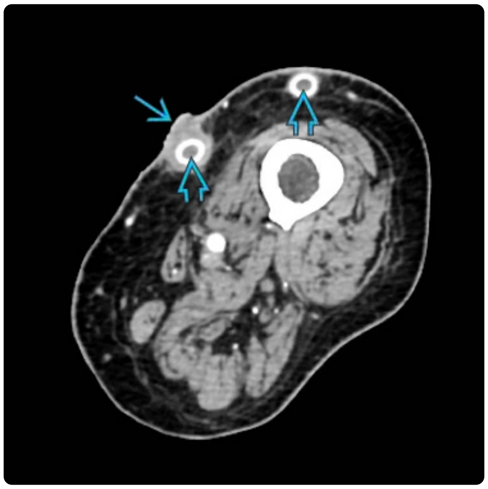


HeRO Graft

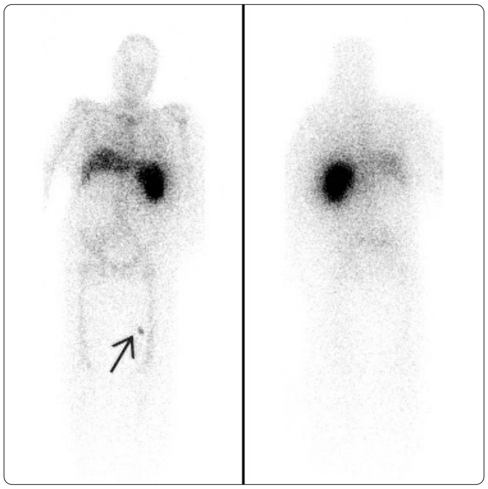


(Left) *A HeRO graft is an alternative access for patients with limited access, or central venous stenosis/occlusion comprised of an intravascular venous outflow component →, and a tunneled subcutaneous arterial graft component ⇨. Note prior stenting of the left brachiocephalic ➡ and right subclavian ➡ vein.* **(Right)** *(Top) Titanium connector ↪ attaches the venous outflow component → to the subcutaneous arterial ePTFE graft ⇨, which (bottom) anastomoses ↪ with the distal brachial artery.*

Thrombosed and Infected Thigh AVG (CT Imaging)



Thrombosed and Infected Thigh AVG (^{111}In Tagged WBC Scan)



(Left) *A patient dialyzing via a left thigh loop graft presented with intermittent fevers, a focal area of swelling at the venous limb, and AVG thrombosis. CTA showed the area of phlegmon → around the venous limb and confirmed AVG thrombosis ⇨.* **(Right)** *^{111}In tagged WBC scan was showing focal uptake in the venous limb of the graft →. HD access infection is an absolute contraindication to percutaneous intervention as it can precipitate bacteremia and septic emboli.*

Hemodialysis Access Declotting Procedures

KEY FACTS

PREPROCEDURE

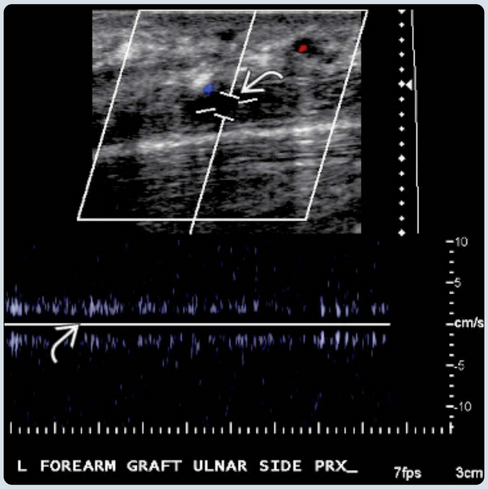
- Contraindications: Access infection, poor cardiopulmonary reserve, recent access creation/revision, right-to-left shunt, severe ipsilateral steal syndrome, hyperkalemia, fluid overload, hemodynamic instability

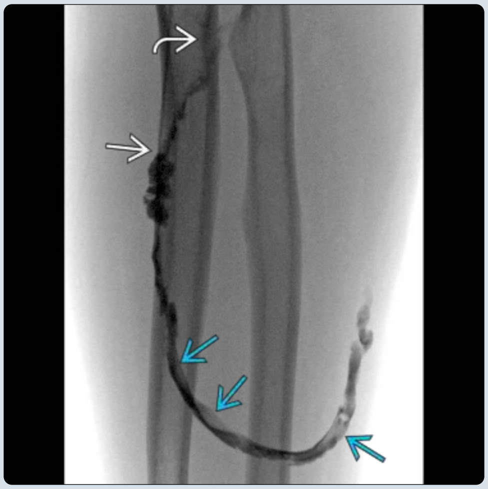
PROCEDURE

- Place facing but nonoverlapping sheaths
- Deliver systemic anticoagulation (e.g., heparin)
- Clear outflow before turning attention to inflow
- Identify and correct inciting stenoses after clot cleared
  - **Pharmacomechanical thrombolysis (PMT)**
    - Pulse-spay 2-6 mg of TPA throughout clotted segment
    - Macerate clot with 6- to 7-mm balloon
    - Perform Fogarty thrombectomy of arterial plug
  - **Mechanical thrombectomy/clot dissolution**
    - e.g., Arrow-Trerotola Percutaneous Thrombolytic Device (PTD), Argon CLEANER XT
    - Can be used ± giving TPA
  - **Lyse and wait**
    - Prior to entering procedure room, prep focal area of access near arterial anastomosis
    - Place 18-g Angiocath or 3-Fr catheter into access
    - Compress arterial and venous anastomoses, inject 2-4 mg of TPA
    - Allow 20-120 minutes of dwell time before bringing patient to procedure room
  - **Thromboaspiration**
    - Place 2 facing nonoverlapping 8- to 9-Fr sheaths
    - Aspirate via sheath or angled tip aspiration catheter
  - **Catheter-directed thrombolysis**
    - Rarely used; consider for large outflow/central clot burden, or failure of above methods

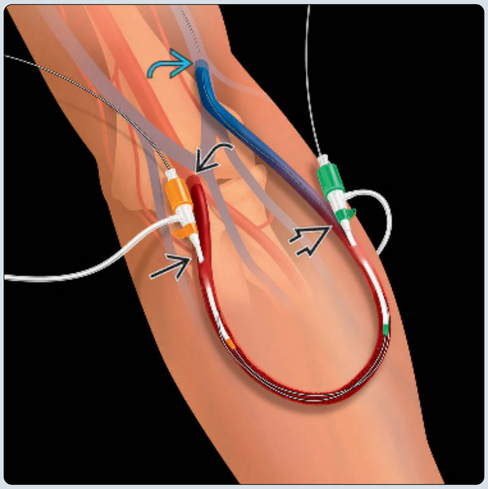
POST PROCEDURE

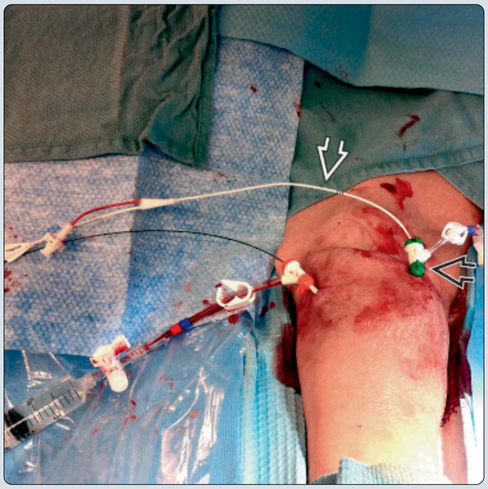
- High immediate success rate
- Primary patency: 25-50% at 6 mos, 10-20% at 12 mos


Clotted Loop AVG


Initial Venogram

(Left) *No pulse, thrill, or bruit could be detected in this patient with a forearm loop graft-to-vein anastomosis (AVG). Initial color Doppler US confirmed thrombosis. No signal is present on pulse wave Doppler ⇨. Grayscale images show increased intraluminal echogenicity also consistent with thrombosis.* **(Right)** *After obtaining antegrade access ➡ just downstream from the arterial anastomosis ⇨, a small-volume, low-pressure injection was done confirming clotted AVG. Note the multiple filling defects ⇨. Contrast was stagnant.*


Correct AVG Declot Sheath Positioning


Arterial Plug Removal

(Left) *The antegrade sheath ⇨ placed just downstream from the arterial anastomosis ⇨ is used to clear outflow clot and stenoses. The retrograde sheath ⇨ is placed upstream from the venous anastomosis ⇨. This is used to clear the inflow clot and pull the arterial plug.* **(Right)** *After outflow clot has been cleared, attention is turned towards the inflow and arterial plug. Through the retrograde sheath ⇨, a Fogarty balloon ➡ is advanced and inflated in the feeding artery. This is retracted, pulling the arterial plug with it.*

Hemodialysis Access Declotting Procedures

TERMINOLOGY

Definitions

- **Declotting**: Recanalization of thrombosed hemodialysis (HD) access
  - Can be done endovascularly or surgically
    - Endovascular approach preferred
      - Less invasive
      - Access ready for immediate use
      - Underlying stenoses can be identified and corrected
    - Surgery preferred for
      - Aneurysmal fistulas with > 200 cc of clot
      - Left-to-right shunt
      - Poor cardiopulmonary reserve
      - Recently created access
  - Thrombosis is 10x more common in graft-to-vein anastomosis (AVG) than AVF
- **Endovascular declotting**
  - Various nonmutually exclusive methods described
    - Pulse-spray pharmacomechanical thrombolysis
    - Lyse and wait
    - Device-related mechanical thrombolysis/thrombectomy
    - Aspiration thrombectomy
- **Surgical declotting**
  - Requires small incision into access
    - Mechanical thrombus removal

PREPROCEDURE

Indications

- Thrombosed hemodialysis AVF or AVG
  - Diagnosed by lack of palpable pulse and thrill and absence of audible bruit

Contraindications

- Access infection: May cause septic emboli, precipitate severe sepsis
- Recent access creation (< 4 weeks old)
  - Potential for suture disruption
  - Poor patency rates
  - Surgical revision and correction of underlying surgical problem preferred
- Left-to-right shunt: Risk paradoxical cerebral embolus
- Large thrombus burden: Large volume of clot creates potential for symptomatic pulmonary embolism
- Poor cardiopulmonary reserve: Potential for decompensation when small clots embolize to lungs
- Multiple declotting procedures in short time span: > 2 access thromboses in 1 month → strongly consider new access creation
- Ipsilateral dialysis associated steal syndrome
- Severe contrast allergy: Use CO_2 instead
- Uncorrectable coagulopathy
- **Temporary Contraindications**
  - Elevated serum potassium (K > 6 mmol/L); EKG changes
  - Hemodynamic instability

Preprocedure Imaging

- Previous AVF/AVG angiograms
  - Shows access configuration
  - Identify severity/location of previous stenosis
- On table ultrasound
  - Assess volume of clot burden, location of arterial anastomosis, most central extension of clot

Getting Started

- Things to check
  - **AVF vs. AVG**
    - AVF
      - Early (e.g., < 48 hours) declot necessary for success; thrombus incites inflammatory reaction
      - Site(s) of stenosis variable
      - Patency maintained despite multiple severe stenoses expected
    - AVG
      - Successful declot possible months after initial thrombosis; thrombus relatively inert
      - Site of stenosis most often venous anastomosis
      - Thrombosis can occur with mild/moderate stenosis
  - Clinical history and physical evaluation
    - Last HD session: Assess need for temporary HD catheter for volume overload, possibility of hyperkalemia
    - Cardiopulmonary insufficiency: e.g., oxygen-dependent COPD, EF < 25%
    - Volume of thrombus burden: e.g., aneurysmal fistula with clot extending into central veins
      - With large volume, can consider overnight catheter-directed TPA infusion
    - HD-associated "steal syndrome": Ischemic ulcers in fingers ipsilateral to access
    - Contraindications to TPA: Recent surgery, intracranial hemorrhage, active or recent GI/GU bleeding
      - Use mechanical devices
    - Flow direction in loop AVG: Review previous imaging, ask patient, evaluate by ultrasound
  - Pertinent laboratory parameters
    - Serum potassium level: Hyperkalemia concerning
      - Mild elevation (< 6 mEq/L) acceptable if ECG normal
    - Coagulation profile: International normalized ratio ≤ 3.5 acceptable
  - Allergies: Typical concern: Contrast, heparin, TPA, latex
  - Consent: Include dialysis catheter placement in case salvage not successful
- Medications
  - Sedative/analgesic agents
    - Moderate sedation
      - Fentanyl (Sublimaze)
      - Midazolam (Versed)
    - Lidocaine 1-2% for local anesthesia
  - Systemic anticoagulation
    - Heparin: 50-70 U/kg bolus to start
    - Bivalirudin (Angiomax): Patients with heparin allergy
  - Thrombolytic agent
    - Recombinant tissue plasminogen activator
      - 2-8 mg depending on volume of clot burden
  - Prophylactic antibiotics (optional)
    - Cefazolin 1-g IV
    - Vancomycin 500-mg IV

- Equipment list
  - Micropuncture set
  - Guidewires
    - Hydrophilic guidewire: Angled or straight tipped
    - Stiff non-hydrophilic guidewire (e.g., Amplatz, Rosen)
  - Sheaths
    - 2 sheaths (7 or 11 cm long)
    - French size dependent on approach taken
    - Bright tip aids visualization
  - Catheters
    - Directional catheter (e.g., Kumpe/Berenstein)
    - Multisidehole infusion catheters (short shaft, 5-10 cm working length)
      - Cragg-McNamarra (Covidien)
      - Uni*Fuse (AngioDynamics)
  - Angioplasty (PTA) balloon catheter
    - 6- or 7-mm balloon for clot maceration in AVG
    - Appropriately sized balloon to treat underlying venous stenosis
      - Typically 7-8 mm at graft venous anastomosis and within outflow (e.g., cephalic) vein
      - Typically 4-5 mm at arterial anastomosis
      - High-pressure balloon usually required
      - Cutting balloon for resistant lesions
  - Embolectomy catheter
    - Fogarty balloon embolectomy catheter (Edwards Lifesciences; Irvine, CA)
  - Mechanical/pharmacologic thrombolysis equipment
    - Rotational basket: Cleaner XT (Argon Medical; Plano, Tx); Arrow-Trerotola Percutaneous Thrombolytic Device (PTD)
    - Rheolytic: AngioJet (Boston Scientific; Marlborough, MA)
  - Stents
    - Self-expanding, covered stents preferred
      - Viabahn endoprosthesis (Gore; Newark, DE)
      - Fluency endovascular stent (Bard; Covington, GA)

PROCEDURE

Procedure Steps

- **Pharmacomechanical thrombolysis (pulse-spray aided)**
  - Sterilely prepare/drape skin overlying AVF/AVG
  - Place antegrade sheath (sheath #1)
    - 1-2 cm downstream from arterial anastomosis
      - Antegrade direction (i.e., toward venous outflow)
      - US guidance: Confirms thrombus within AVF/AVG; aids percutaneous access (typically no blood return)
  - Through sheath #1
    - Evaluate central venous outflow
      - Advance directional catheter (Berenstein) and wire (angled glide) centrally
      - Perform central venogram
      - Administer systemic heparin, sedation (via catheter or separate IV)
      - Perform pullback venogram; assess central extension of clot
      - Treat underlying central stenoses or occlusion
    - Exchange directional catheter for multisidehole infusion catheter (Cragg-McNamarra or Uni*Fuse)
      - Pulse-spray 2-6 mg of TPA mixed in 5 to 10 cc of normal saline into thrombus within venous outflow
      - Forceful injections using 0.2-cc aliquots
      - Lace TPA into clot from its central extent to near puncture site of sheath #1
      - Let TPA dwell for 5-15 minutes
  - Place retrograde sheath (sheath #2)
    - 3-4 cm upstream from AVGs or 10-15 cm downstream from sheath #1
    - Retrograde direction (i.e., toward arterial anastomosis)
    - If placed after TPA given through sheath #1, allows for longer dwell time of TPA in venous outflow thrombus
  - Through sheath #2
    - Advance directional catheter toward but not beyond arterial anastomosis
    - Exchange for multisidehole infusion catheter (Cragg-McNamarra or Uni*Fuse)
      - Pulse-spray 2 to 4 mg of TPA into arterial side clot
  - Turn attention to sheath #1
    - Advance non-hydrophilic (Amplatz or Rosen) guidewire centrally into IVC
    - Macerate clot in venous outflow (balloon)
      - Inflate balloon to nominal pressure, push forward
      - Use 6- to 7-mm balloon for AVG and appropriately sized balloon for AVF
      - Start centrally, work back toward sheath entry site
      - Ensure balloon fully deflated when pulled back toward artery
      - Retracting partially inflated balloon could pull clot into feeding artery
    - Alternate: Macerate venous clot (rotational basket)
      - Slowly advance and withdraw mechanical thrombolysis equipment (e.g., Cleaner XT, Arrow-Trerotola PTD)
    - Consider sheath aspiration of clot
    - Optional: gentle venogram to assess for residual clot
      - Care in performing venogram: If significant residual clot or reflux of contrast toward artery seen, stop injecting to avoid arterial embolism
  - Turn attention to sheath #2
    - Advance Glidewire and catheter into feeding artery upstream to anastomosis
    - Exchange for compliant balloon (Fogarty)
    - Inflate balloon upstream from anastomosis and pull back toward sheath #2
      - Platelet plug pulled through patent access and into pulmonary arteries
      - Can aspirate through sheaths to minimize clot fragments embolizing centrally
    - Check patency by opening sheath sidearms, by physical exam, or by ultrasound
      - Access patency often restored at this time
    - Repeat Fogarty arterial embolectomy 2-4 times if necessary
    - Once access is patent, perform angiograms from feeding artery to right atrium
    - Treat offending sites of stenosis

- **Mechanical thrombectomy**: Breaking thrombus into ultra-small particles, allowing suction aspiration or distal passage through capillaries
  - Place facing, nonoverlapping sheaths in standard positions; 6 to 7 Fr dependent on thrombectomy device
    - Arrow-Trerotola PTD: 6 Fr not over wire, or 7 Fr over 0.025" wire
    - Cleaner XT: 6 Fr preferred, stiffer 7 Fr available
  - Evaluate central venous outflow
    - Advance wire and catheter through antegrade sheath into central veins
    - Perform central venogram and administer systemic heparin, antibiotics, and sedation
    - Perform pullback venogram to evaluate central most extension of thrombus and presence of central occlusion/stenosis
  - Advance compressed basket of mechanical rotational device through antegrade access to central most clot
    - Slide sidearm back to expose basket
    - Activate basket rotation device on and slowly pull it through clot towards antegrade sheath while basket is rotating
      - Cleaner XT sidearm allows TPA delivery during active rotation if needed
    - Pull device through clot toward antegrade sheath while basket is rotating
    - Once device at sheath tip, slide sidearm to compress basket and remove device over wire
    - Aspirate clot slurry from sheath
      - May be difficult to aspirate given closed system
    - Clean PTD device on table
      - Manually remove any fibrin from basket
    - Repeat venous outflow mechanical thrombectomy 2-4 times
  - Perform gentle venogram through antegrade sheath
    - Optional evaluation for residual thrombus
  - Turn attention to retrograde sheath
    - Cannulate upstream feeding artery with wire and catheter combination
    - Insert compressed basket through retrograde sheath just downstream to arterial anastomosis
    - Open basket
      - Ensure that basket does not jump forward; do not grip outer constraining catheter while pulling back sidearm lever
      - Would accidentally push arterial plug into feeding artery
    - Turn device on and pull rotating basket toward retrograde sheath
    - Once basket is at tip of sheath, slide sidearm forward to compress basket and remove device over wire
    - Repeat mechanical thrombectomy of inflow 3-4 times
  - Pull arterial plug
    - Fogarty embolectomy as described above
  - Once flow reestablished, perform angiogram from feeding artery
    - Treat causative stenoses
- **Lyse and wait**
  - Prep focal area of access near arterial anastomosis
  - Use ultrasound guidance, puncture access with 18-g Angiocath/3-Fr micropuncture set in antegrade direction
    - Confirm intraaccess location
      - Visualization with ultrasound
      - With free passage of 0.018" wire
      - By aspiration of small amount of clot
  - Inject 2 to 4 mg of TPA while compressing arterial and venous anastomoses for 60 seconds
    - Cap catheter and place under Tegaderm
    - Allow to dwell 20-120 minutes
  - Bring patient into procedure room
    - Prep/drape entire access including existing catheter
  - Exchange catheter for 6-Fr sheath
    - Advance wire and catheter centrally
    - Administer sedation, antibiotics, and heparin
    - Perform central venogram, treat underlying central occlusions or stenoses
    - Perform pullback venogram
      - Balloon macerate of residual clot
  - Obtain retrograde access near venous anastomosis or 10-15 cm downstream from initial access
    - Place 6-Fr sheath
    - Advance wire into upstream artery
  - Perform mechanical thrombectomy of arterial plug using compliant (Fogarty) balloon as described previously
  - Once patency confirmed perform angiogram from feeding artery
    - Treat offending stenoses
- **Thromboaspiration**
  - Ultrasound to assess for extent of clot burden
  - Place 2 facing, nonoverlapping 8- to 9-Fr sheaths in standard positions
  - Advance catheter/wire centrally through antegrade sheath
    - Perform central venogram and correct underlying central stenosis
    - Deliver **heparin**, sedation, and antibiotics
    - Perform pullback injection to evaluate central most extension of clot
  - Perform thromboaspiration of venous outflow
    - Exchange diagnostic catheter for angled tip aspiration catheter
    - Start aspiration at central most portion of clot
    - Apply suction with 20- to 30-mL syringe while rotating and moving catheter back and forth rapidly
    - Remove catheter via sheath with suction still applied
    - Flush catheter, ejecting clot onto piece of gauze
    - Repeat multiple times moving from central most portion of clot back towards tip of antegrade sheath until no further clot can be removed
  - Perform thromboaspiration of inflow via retrograde sheath
    - Perform aspiration starting at tip of retrograde sheath, progressing upstream toward anastomosis with each subsequent pass
    - Perform thrombectomy of arterial plug using compliant (Fogarty) balloon
      - Given its compact nature, arterial plug is often difficult to aspirate
      - Successful aspiration requires significant manipulation and risks fragmentation/dislodgement of arterial plug

    - Check patency of access after each pass by opening up sidearms of sheaths
    - If flow is present, perform angiogram from feeding artery
    - Address underlying stenoses
- **Catheter-directed thrombolysis**
  - Gain access as above, determine central extent of thrombus
  - Place crossing infusion catheters, extending past thrombus
  - Infuse TPA at 0.5-1.0 mg/hour for 12-24 hours
  - When to consider use
    - AVF with large outflow/central clot burden; patient with limited cardiopulmonary reserve at risk from dislodged thrombus (i.e., pulmonary embolus)
    - AVF with longstanding (e.g., > 48 hours) thrombosis
    - Failure of declotting techniques listed above
- **Concluding procedure**
  - Evaluate AVF/AVG for thrill
    - Good thrill predictive of subsequent patency
  - If patient going to dialysis after procedure, exchange for dialysis sheaths
  - If patient not going to dialysis, remove sheaths and achieve hemostasis using purse-string sutures or compression
    - Avoid over compression as this could cause repeat thrombosis

Findings and Reporting

- Document access flow from inflow artery to right atrium
- Medications and devices used

Alternative Procedures/Therapies

- Surgical
  - Surgical thrombectomy
    - Thrombosis of freshly created access
    - Right-to-left shunt
    - Poor cardiopulmonary reserve
    - Mega-fistula with large volume of clot

POST PROCEDURE

Things to Do

- Examine hand for signs of ischemia
- Assure adequate hemostasis

Things to Avoid

- **Arterial embolization**
  - Do not flush sheaths after placement
    - Increased volume and pressure in access could push clot into feeding artery
  - Minimize contrast injections into clotted access
    - Use slow injection and with small volumes
      - ☐ Stop injection if there is retrograde flow or significant residual clot
  - Minimize manipulations near arterial anastomosis
    - e.g., when placing retrograde sheath, starter wire should not cross arterial anastomosis
  - Clear outflow before turning attention to inflow
    - Perturbed clot will preferentially flow centrally rather than into feeding artery
  - Fully deflate balloons when they are moved toward arterial anastomosis
  - Do not perform manual occlusion retrograde angiogram to check inflow
    - Small amount of remaining thrombus can be swept into artery
      - ☐ Perform angiogram from feeding artery instead
- **Treatment of arterial embolization**
  - Observation if asymptomatic
  - Backbleeding: Occlude upstream feeding artery and allow collaterals to create retrograde flow distal to clot, pushing clot back into and through patent AVG/AVF
  - Fogarty embolectomy: Advance balloon distal to clot, pull clot back into and through access
  - TPA lysis: Often difficult given platelet-rich arterial plug
  - Aspiration: Often difficult given compact nature of plug
    - Risk further fragmentation/distal showering of clot
  - Surgical embolectomy if above maneuvers fail

OUTCOMES

Problems

- Failure to recanalize thrombosed AVF/AVG
  - Chronic clot
  - Uncorrectable stenosis(es) or occlusion

Complications

- Most feared complication(s)
  - Arterial embolism/ischemic limb
  - Paradoxical embolism (stroke)
  - Symptomatic pulmonary embolism
- Immediate/periprocedural complication(s)
  - Septic embolism
  - Venous rupture
  - Anastomotic disruption
  - Clinically significant bleeding remote from access is < 0.1%

Expected Outcomes

- Technical Success
  - Reestablish flow in access
  - Permits at least 1 adequate HD treatment
  - AVG > 95%; AVF ~ 80-90%
    - Early intervention in AVFs important
      - ☐ Vein scarring and adherent clot can occur in thrombosed AVFs
- Primary patency following declot: 25-50% at 6 months and 10-20% at 12 months
  - Similar for both AVFs and AVGs

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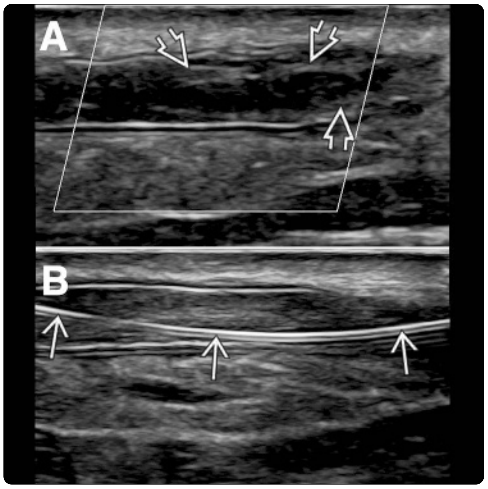
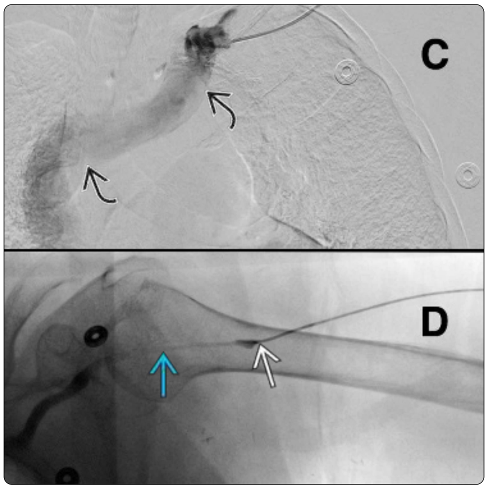
2. Bent CL et al: The radiological management of the thrombosed arteriovenous dialysis fistula. Clin Radiol. 66(1):1-12, 2011
3. Yurkovic A et al: Outcomes of thrombectomy procedures performed in hemodialysis grafts with early failure. J Vasc Interv Radiol. 22(3):317-24, 2011

Step-by-Step: Pharmacomechanical AVG Thrombolysis (Initial Ultrasound)

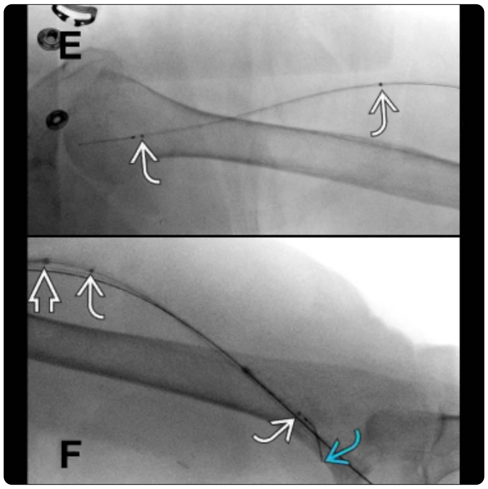


Step-by-Step: Pharmacomechanical AVG Thrombolysis (Initial Venograms)

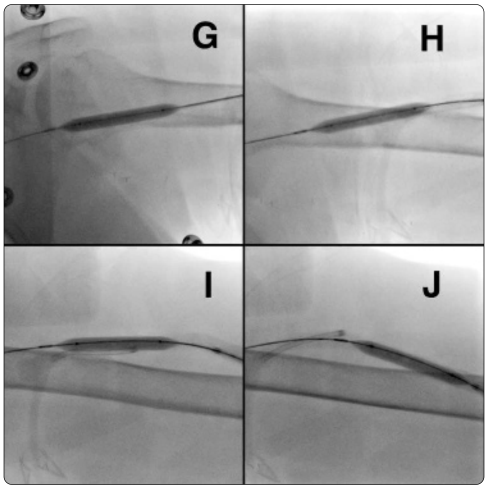


(Left) *(A) Initial color Doppler ultrasound confirms lack of flow. Clot can be seen on grayscale imaging ➡. (B) Antegrade access is obtained just downstream from the arterial anastomosis. As no flash-back of blood occurs when puncturing a clotted access, ultrasound should be used. Note the intraluminal passage of the wire ➡.* **(Right)** *(C) Central venography ⇨ is done next. Severe stenoses or occlusions should be treated. (D) The catheter ➡ is then retracted while injecting contrast to identify the central most extension of clot ⇨.*

Step-by-Step: Pharmacomechanical AVG Thrombolysis (TPA Administration)

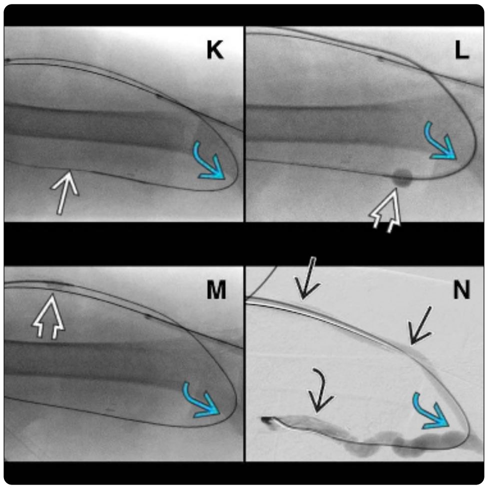


Step-by-Step: Pharmacomechanical AVG Thrombolysis (Balloon Maceration)

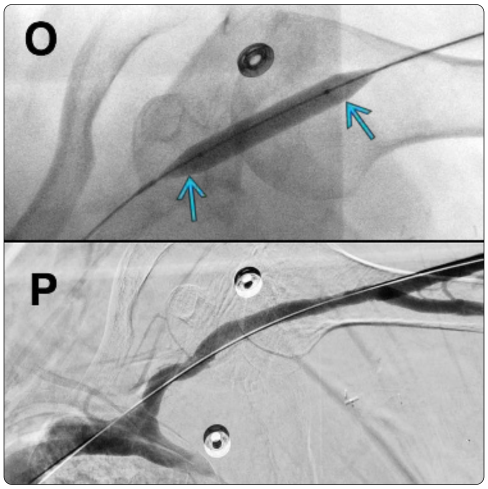


(Left) *(E) TPA is then administered through a multisidehole infusion catheter, such as a Uni*Fuse ➡. (F) Start with the central most clot. Work back to the antegrade puncture site. While TPA dwells in the outflow clot, obtain retrograde access ➡. TPA is then administered into the inflow up to but not across the arterial anastomosis ⇨.* **(Right)** *Balloon (or rotational basket) maceration is done next. Start centrally (G) and move peripherally (J). Ensure that the balloon is fully deflated whenever it is moved toward the artery.*

Step-by-Step: Pharmacomechanical AVG Thrombolysis (Arterial Plug)



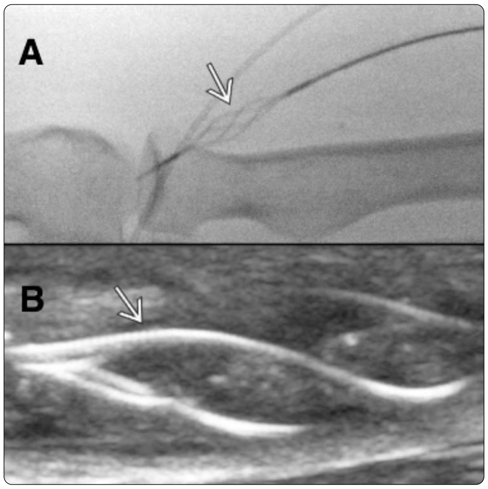
Step-by-Step: Pharmacomechanical AVG Thrombolysis (Treatment of Stenosis)



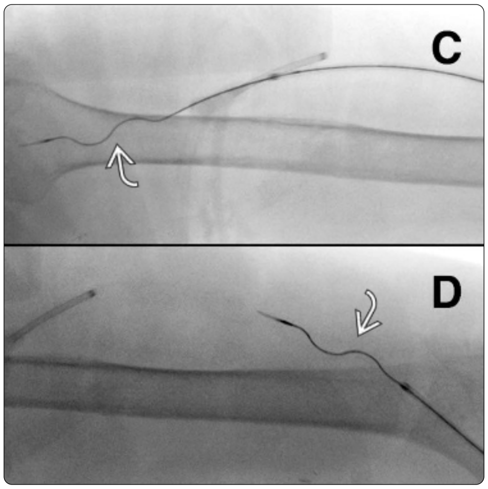
(Left) *The arterial plug must now be addressed. After catheterizing the upstream artery ➡ (K), a Fogarty embolectomy catheter is placed. This is inflated ➡ in the feeding artery (L) and pulled back across the anastomosis ⇨ (M) to the retrograde sheath. Repeat injection from the upstream artery ⇨ shows access patency ⇨.* **(Right)** *The causative stenosis should then be identified. Narrowing at the AVG was present and treated with 7-mm balloon angioplasty ⇨ (O) to good effect (P).*

(Left) *Mechanical devices can be used to macerate clot. Spot fluoroscopy (A) and ultrasound (B) of the Arrow-Trerotola percutaneous thrombolytic device is shown. The rotating nitinol basket* ➡ *spins at 3,000 revolutions per minute, macerating clot into a slurry which can then be aspirated.* **(Right)** *Another mechanical device is the Argon Cleaner whose self-sizing atraumatic sinusoidal wire* ↪ *rotates at 4,000 RPM.*

Mechanical Thrombectomy Device (Arrow-Trerotola PTD)

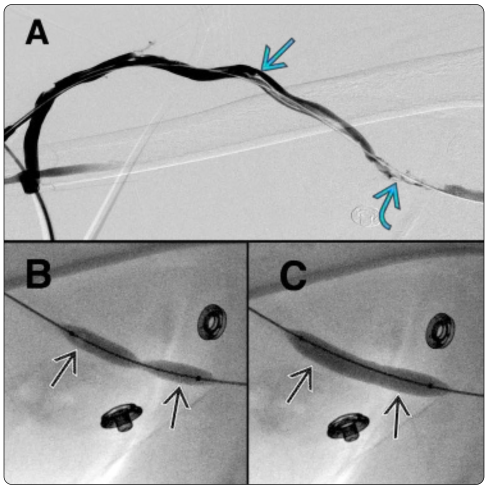


Mechanical Thrombectomy Device (Argon Cleaner XT)

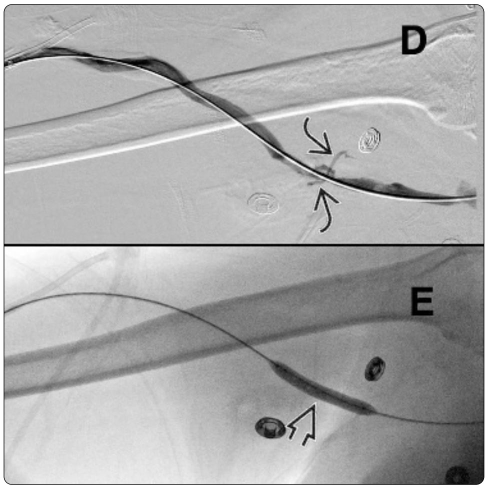


(Left) *This AVG was created 3 weeks prior to declot. Standard pulse-spray-aided pharmacomechanical AVG thrombolysis techniques were used, clearing all but a small amount of clot* ⇨ *around the retrograde sheath (A). Severe irregular stenosis is seen at the venous anastomosis* ↪*. This was treated with angioplasty using 7-mm balloon* →*.* **(Right)** *(D) Follow-up angiogram showed focal extravasation* ↪*. Attempts were made to treat this with low-pressure balloon* ⇨ *tamponade for 5 minutes (E).*

Declot of Freshly Created AVG: Venous Anastomotic Rupture (Successful Declot)

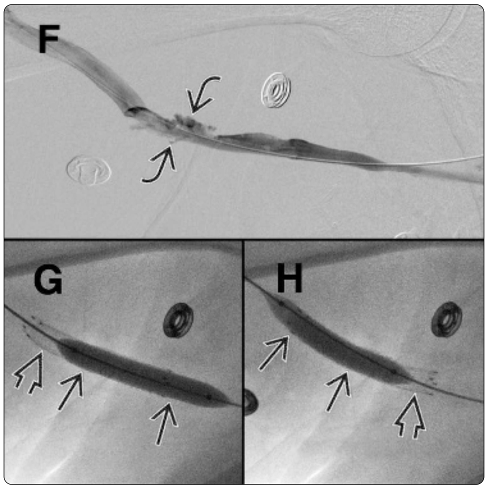


Declot of Freshly Created AVG: Venous Anastomotic Rupture (Tamponade)

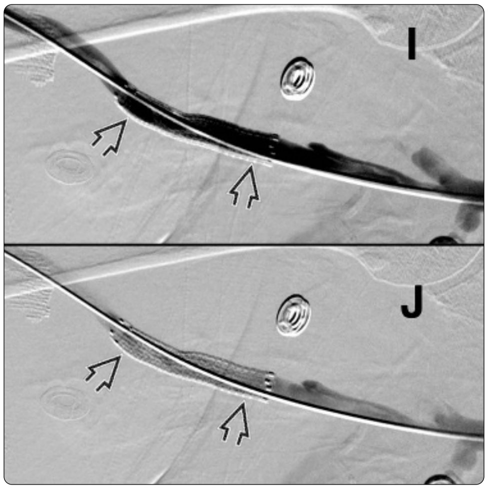


(Left) *(F) Despite 2 rounds of tamponade, extravasation continued* ↪*. (G and H). A 7 mm x 5 cm self-expanding covered stent* ⇨ *was placed across site of extravasation. Post deployment angioplasty was performed with 7-mm diameter balloon* →*.* **(Right)** *After stent graft placement* ⇨*, no residual stenosis or extravasation was seen (I and J). Declotting of freshly created AV accesses should be carefully considered because of the potential for disruption of fresh suture lines and poor overall patency rates (0% at 3 months).*

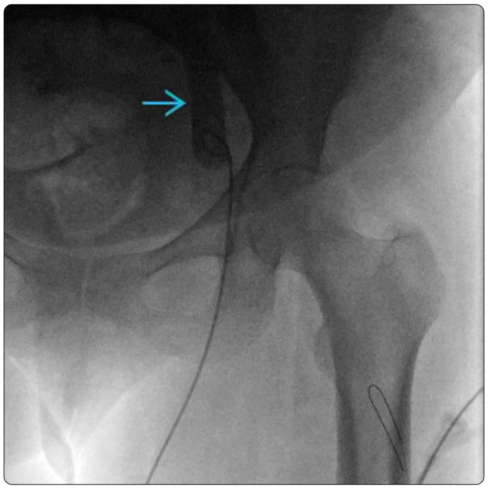
Declot of Freshly Created AVG: Venous Anastomotic Rupture (Stent Deployment)



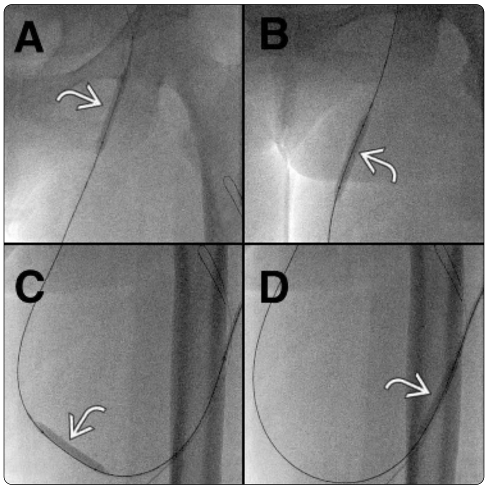
Declot of Freshly Created AVG: Venous Anastomotic Rupture (Final DSA)



Femoral Loop Graft: Pulse-Spray-Aided PMT (Outflow Venogram)

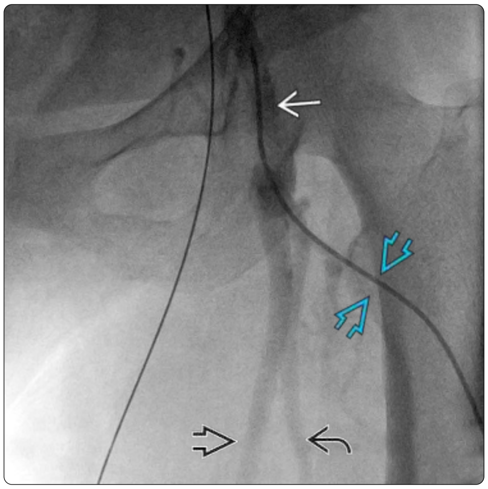


Femoral Loop Graft: Pulse-Spray-Aided PMT (Clot Maceration)

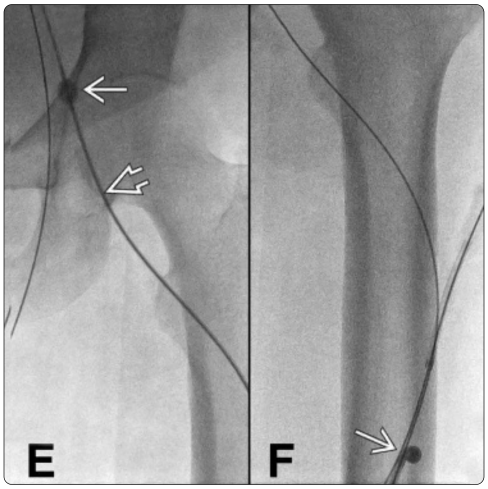


(Left) *Antegrade access is obtained and venography is performed, confirming patency of the outflow veins* ⇨*. Pull back injection is then done to assess the most central extension of clot, which typically is near the venous anastomosis.* **(Right)** *After administering 3 mg of TPA to the outflow clot through a multisidehole infusion catheter, maceration of the clot was undertaken with a 6-mm balloon* ⇨*. One should start at the most central aspect (A), working back toward the arterial anastomosis (D).*

Femoral Loop Graft: Pulse-Spray-Aided PMT (Inflow Arteriogram)

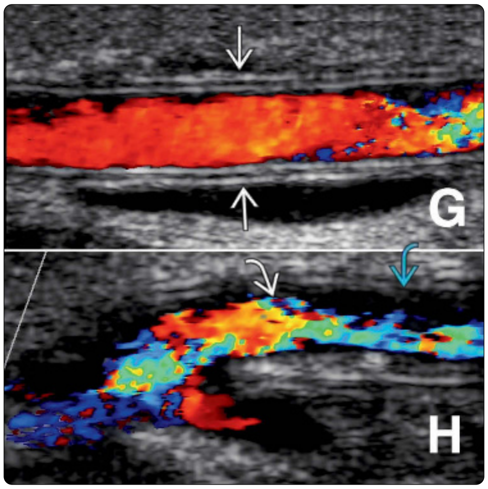


Femoral Loop Graft: Pulse-Spray-Aided PMT (Arterial Plug Embolectomy)

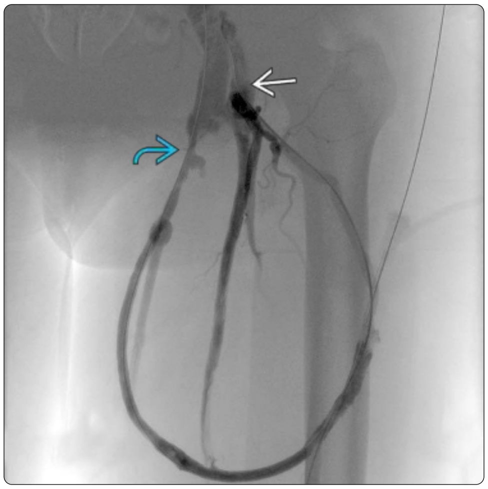


(Left) *The feeding CFA* → *was cannulated through the retrograde sheath. An angiogram shows a patent superficial femoral artery* ⇨ *and profunda femoris artery* ↷*. The AVG* ⇨ *is not patent.* **(Right)** *To clear the arterial plug, a Fogarty embolectomy is used. Over a wire, the deflated compliant balloon is advanced into the feeding artery upstream to the arterial anastomosis. The balloon* → *is then inflated (E) and pulled back across the anastomosis* ⇨ *and into the access, pulling the arterial plug with it (F).*

Femoral Loop Graft: Pulse-Spray-Aided PMT (Underlying Venous Stenosis)



Femoral Loop Graft: Pulse-Spray-Aided PMT (Underlying Venous Stenosis)



(Left) *After arterial plug embolectomy, patency of the access should be restored. This can be confirmed by physical examination, opening the sheath sidearm, angiogram from the feeding artery, or color Doppler ultrasound as done here. The midbody of the graft (G) was widely patent* →*. Aliasing* ↷ *and stenosis* ↷ *was seen near the venous anastomosis (H).* **(Right)** *Angiography from the inflow artery* → *confirmed AVG patency. Venous anastomotic stenosis* ↷ *(a classic site) was seen and subsequently treated.*

Transjugular Biopsy

KEY FACTS

TERMINOLOGY

- **Transvenous biopsy (TVB)**: Random (nonfocal) biopsy of liver or kidney via transvenous introduction of cannula/biopsy needle
- **Transvenous hepatic manometry (TVHM)**: Intrahepatic pressure measurements obtained via transvenous access, often accompanied by TVB, to estimate portal perfusion pressure

PREPROCEDURE

- Indications
  - TVB: Suspected diffuse hepatic/real parenchymal disease with contraindication to or failed percutaneous biopsy
  - TVHM: Diagnosis or evaluation of portal hypertension
- Contraindications
  - Focal lesion without diffuse parenchymal disease
  - Severe, uncorrected coagulopathy
  - Lack of appropriate access
  - Hepatic/renal vein occlusion

PROCEDURE

- Obtain right internal jugular or femoral venous access
- Selectively catheterize right hepatic/renal vein
  - Confirm catheter position with contrast injection (contrast or CO_2)
- Perform hepatic manometry if indicated
- Obtain 3-4 biopsies through 7-Fr introducer sheath
- Postbiopsy venography to evaluate for capsular perforation
  - Embolization with Gelfoam or coils as needed

POST PROCEDURE

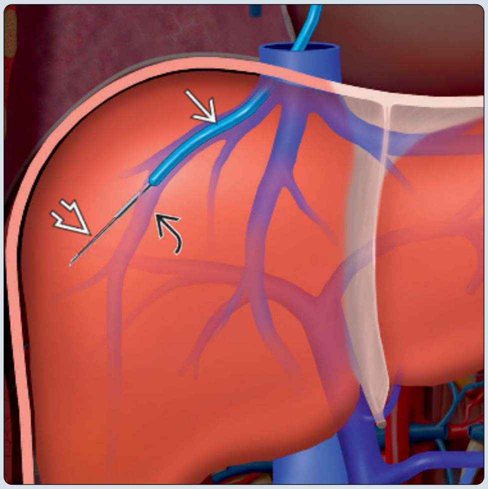
- Technical success: > 92%
- Tissue adequacy: > 95%

OUTCOMES

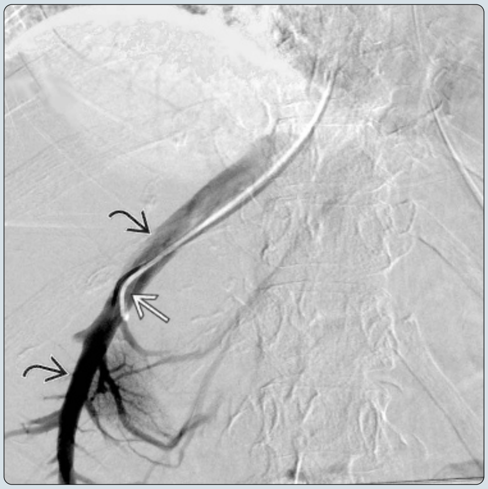
- Minor complications (6%)
- Major complications: Hemorrhage (1%), death (0.1%)

(Left) *Guiding sheath ➡ is positioned in the right hepatic vein (RHV) ↪ via transjugular access. The biopsy needle ⇨ is advanced out of the sheath into the liver parenchyma to obtain a sample.* **(Right)** *In preparation for transjugular hepatic biopsy, a multipurpose angled catheter ➡ is positioned into the RHV ↪. DSA imaging with contrast confirms appropriate catheter position.*

Transjugular Hepatic Biopsy (Graphic)

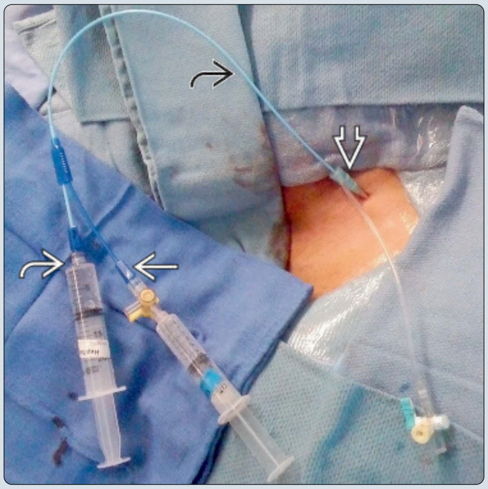


Transjugular Hepatic Biopsy (Catheter Positioning)

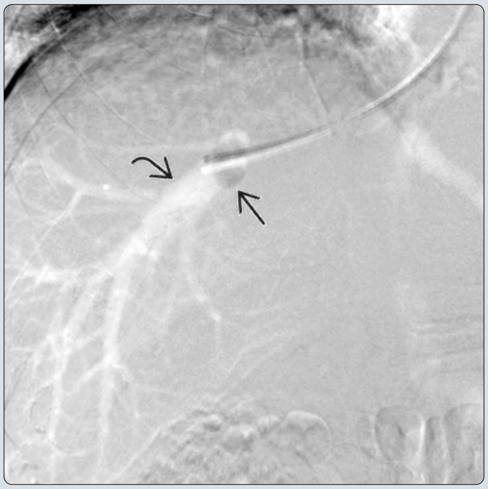


(Left) *Occlusion balloon catheter ↪ is introduced via jugular vein sheath ⇨ after selection of the RHV with multipurpose catheter. Two ports are available, one for contrast injection ↪ and the other for balloon inflation ➡.* **(Right)** *Following selection of the RHV ↪, CO_2 venography was performed to demonstrate adequate occlusion via balloon catheter →. Wedged hepatic venous pressure is also obtained in this manner.*

Transjugular Liver Manometry (Occlusion Balloon Venography)



Transjugular Liver Manometry (Occlusion Balloon Venography)



TERMINOLOGY

Definitions

- **Transvenous biopsy (TVB)**: Random (nonfocal) biopsy of liver or kidney via transvenous access
  - Transjugular biopsy: Preferred access via right internal jugular vein due to relatively straight path
  - Transfemoral biopsy: 2nd-line access via femoral vein in cases of central venous occlusion
- **Transvenous hepatic manometry (TVHM)**: Intrahepatic pressure measurements obtained via transvenous access
  - **Free hepatic venous pressure (FHVP)**: Reflects intraabdominal vena cava pressure, obtained in hepatic vein
  - **Wedged hepatic venous pressure (WHVP)**: Reflects sinusoidal pressure, obtained in hepatic vein via occlusion
  - **Hepatic venous pressure gradient (HVPG)**: Reflects portal perfusion pressure, calculated as WHVP - FHVP
    - Normal: < 5 mm Hg
    - Portal Hypertension: > 10 mm Hg

PREPROCEDURE

Indications

- **TVB**
  - Suspected hepatic/renal parenchymal disease with
    - Contraindication to percutaneous biopsy
    - Failed percutaneous biopsy
    - Coexisting need for TVHM
- **TVHM**
  - Diagnose portal hypertension
  - Predict complications of chronic liver disease
  - Evaluate response to treatment
    - β-blocker prophylaxis
    - Antiviral therapy in setting of hepatitis B
    - Evaluate stenosis of transjugular intrahepatic portosystemic shunt

Contraindications

- Lack of appropriate venous access
- Central hepatic/renal vein occlusion
- Severe, uncorrectable coagulopathy

Preprocedure Imaging

- Review priors if available for venous anomalies and patency

Getting Started

- Things to check
  - Clinical history and physical examination
    - Procedure indications
    - Current medications (anticoagulants, antiplatelets)
  - Allergies
  - Laboratory parameters
    - Electrolytes, creatinine
    - Complete blood count: Platelet > 50,000/μL
    - Coagulation profile
      - International normalized ratio: Prefer ≤ 1.5
      - Normal prothrombin time, partial thromboplastin time
  - Consent: Discuss possible postprocedural pain, hemorrhage
- Medications
  - Sedation is often used (usually fentanyl/midazolam)
  - Antibiotics typically unnecessary
- Equipment list
  - Micropuncture access kit
  - Catheters/sheaths
    - 9- or 10-Fr vascular access sheath
    - 5-Fr multipurpose angled (MPA) catheter
    - 7-Fr guide sheath with stiff, curved, metal cannula
  - Guidewires
    - 0.035" straight or J-curve tip guidewire
    - 0.035" angled hydrophilic guidewire
    - 0.035" Amplatz stiff guidewire
  - Biopsy needle (commercially available sets)
    - 18- or 19-g needle with 20-mm specimen notch
  - Sample collection containers
    - Formalin &/or saline
    - Metal-free container required for hemachromatosis
  - Hepatic manometry
    - Pressure transducer
    - Balloon occlusion catheter (optional)

PROCEDURE

Patient Position/Location

- Supine
- Transjugular access preferred, but transfemoral access may be considered in patients with central venous occlusion

Procedure Steps

- **Initial steps**
  - Sterilely prep and drape skin access site
  - Administer 1% lidocaine for local anesthesia
  - Obtain percutaneous venous access
  - Upsize introducer to 9- or 10-Fr vascular access sheath
  - Advance guidewire into inferior vena cava (IVC) followed by 5-Fr catheter
- **Hepatic manometry (optional)**
  - Zero pressure transducer at midaxillary height
  - Obtain R atrial and infrahepatic pressures via catheter
    - Should be within 2 mm Hg of FHVP, otherwise consider HV outflow stenosis
  - Selectively catheterize right hepatic vein
    - Use hydrophilic guidewire and MPA-type catheter
    - Reverse curve catheter may be helpful
  - Exchange multipurpose catheter for balloon occlusion catheter (optional, samples larger area)
  - Measure FHVP
    - Allow 15-20 seconds for equilibration of pressure
  - Wedge catheter or inflate balloon (as applicable)
  - Measure WHVP
    - Allow 1-2 minutes for equilibration of pressure
  - Perform venography (contrast or CO_2) to confirm successful catheter wedge/vessel occlusion with balloon
    - Perform postmanometry; contrast alters blood viscosity
  - Do not oversedate if performing hepatic manometry
    - Can alter respirations and subsequent measurements
- **Liver biopsy**
  - Exchange catheter/occlusion balloon for 7-Fr guide sheath over stiff, curved inner canula

    - Advance into right hepatic vein over 0.035" Amplatz guidewire
    - Position in proximal right hepatic vein 3-4 cm from IVC
    - Confirm position with venography (contrast or CO_2)
      - Right hepatic vein is posterior, viewed laterally
  - Exchange wire for biopsy needle via 7-Fr guide sheath
  - Rotate 7-Fr guide sheath/canula so tip faces anteriorly
    - Rotate counterclockwise if from internal jugular approach
    - Maintain gentle forward pressure on guide sheath
  - Advance biopsy cutting needle into hepatic parenchyma
    - Activate spring-firing mechanism of needle
    - Remove needle to obtain specimen
    - Reinsert biopsy needle to obtain additional samples
- **Renal biopsy**
  - Selectively catheterize renal vein and subselect posterior lower pole branch
    - Exchange guidewire for hydrophilic wire if needed
  - Confirm position with venography (contrast or CO_2)
  - Exchange for 0.035" Amplatz guidewire
  - Advance 7-Fr guide sheath with stiff, curved inner canula
    - Position distally in cortical lower pole vein
  - Remove Amplatz guidewire
  - Introduce biopsy cutting needle via 7-Fr sheath
    - Position needle at distal end of sheath
    - Maintain gentle forward pressure on guide sheath
  - Advance biopsy cutting needle into renal cortex
    - Activate spring-firing mechanism of needle and remove needle
    - Remove needle to obtain specimen
    - Reinsert biopsy needle to obtain additional samples
- **Post biopsy**
  - Venogram can be performed following biopsy
    - Evaluate for capsular perforation
    - Consider Gelfoam embolization if positive or in high-risk patients

Findings and Reporting

- DSA venography findings
- Hepatic venous pressure measurements
  - Right atrium/infrahepatic IVC
  - FHVP, WHVP, and calculated HVPG
- Location and number of core biopsies obtained
- Any immediate/periprocedural complications

Alternative Procedures/Therapies

- Radiologic
  - Percutaneous biopsy
    - US or CT guidance
- Surgical
  - Open or laparoscopic biopsy

POST PROCEDURE

Things to Do

- Postprocedural bedrest for 2-6 hours
- Vitals every 15 minutes x 4, then every 30 minutes x 2, then hourly x 4 or until discharge

OUTCOMES

Problems

- Inadequate biopsy sample
  - Use larger gauge needle when possible
  - Discuss case-specific tissue requirements with pathology
- Nontarget biopsy
  - Biopsy needle may extend beyond target organ capsule
  - TVB is "blind," whereas percutaneous methods allow direct visualization of parenchyma
- Severe abdominal pain
  - Obtain abdominal CT, exclude intraperitoneal hemorrhage

Complications

- Most feared complication(s)
  - Intraperitoneal hemorrhage (0.6-1.0%)
  - Death (0.1-0.5%)
    - Usually due to severe intraperitoneal hemorrhage
- Immediate/periprocedural complication(s)
  - Abdominal pain (10%)
  - Supraventricular arrhythmia (4-10%)
  - Capsular perforation without intraperitoneal hemorrhage
    - More common with renal biopsy due to closer proximity to capsule
      - Occurs in up to 74-90% of cases
      - Perirenal hematoma in < 30%
- Delayed complication(s)
  - Infection (rare)
  - Venous thrombosis/stenosis at access site
  - Fistula between hepatic vein and artery or bile duct

Expected Outcomes

- Hepatic biopsy
  - Technical success: 97%
  - Tissue adequacy: 96%
- Hepatic manometry
  - Technical success: > 95%
  - To improve accuracy of measurements
    - Minimize sedation that can affect respiration
      - Can administer additional sedation as needed after pressure measurements, prior to biopsy
    - Allow adequate time for equilibration
- Renal biopsy
  - Technical success: 92-96%
  - Tissue adequacy: 98%

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4. Schmid A et al: Transvenous renal transplant biopsy via a transfemoral approach. Am J Transplant. 13(5):1262-71, 2013
5. Jana M et al: Transjugular liver biopsy: tips and tricks. Trop Gastroenterol. 33(3):168-72, 2012
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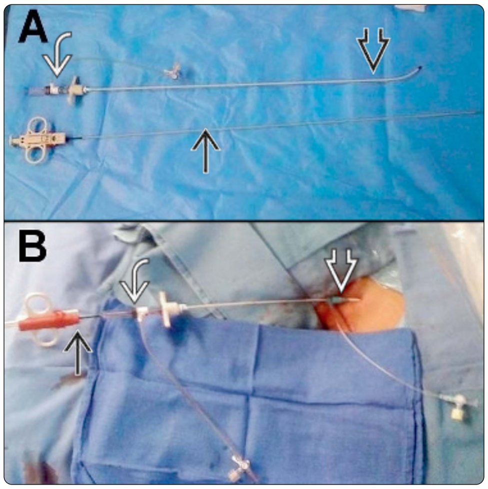
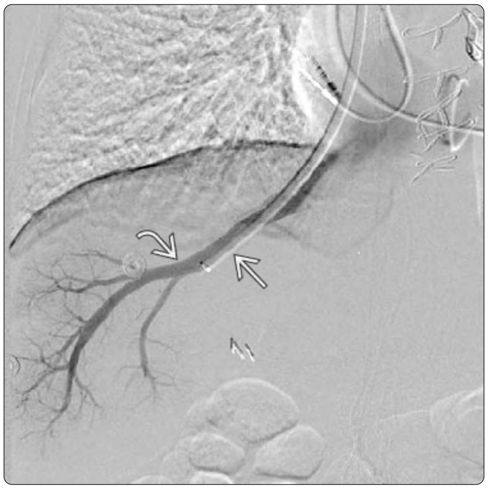
Transjugular Liver Biopsy (Biopsy Needle Kit)

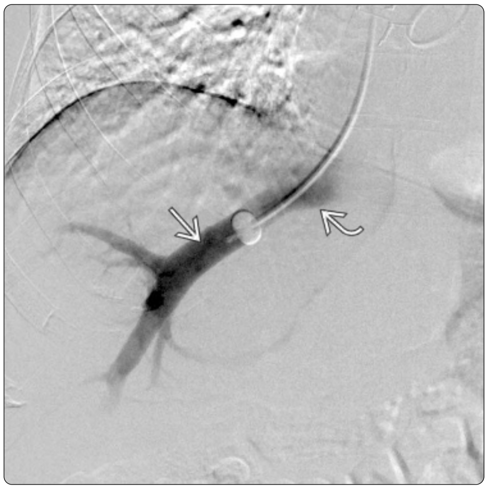


Transjugular Liver Biopsy (Introducer Position)

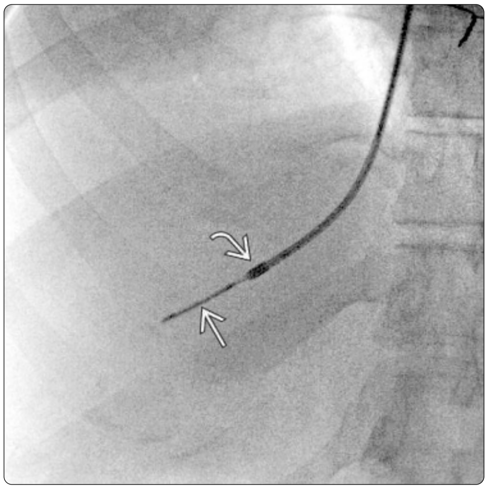


(Left) *(A) Biopsy needle ⇨ is to be advanced through a guiding sheath ⇒ with stiff, curved inner cannula ➦. (B) The guiding sheath was advanced through jugular vein access sheath ➩ into the RHV. After removal of guidewire, the biopsy needle is advanced through the inner cannula into hepatic parenchyma.* **(Right)** *An introducer sheath ➡ was advanced over a wire into the RHV ➦. DSA after removal of wire confirms appropriate position as well as normal arborization and patency of the RHV.*

Transjugular Liver Manometry (Balloon Occlusion)

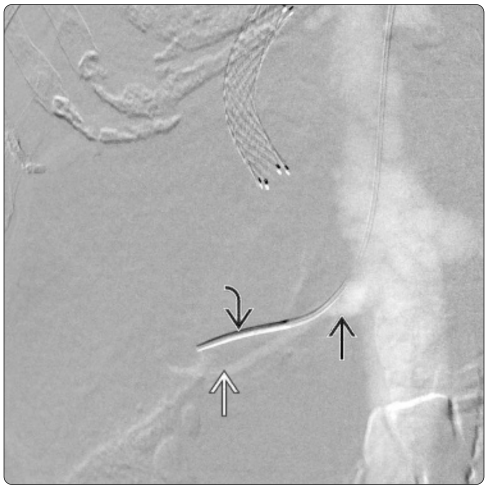


Transjugular Liver Biopsy (Biopsy Needle Sampling)

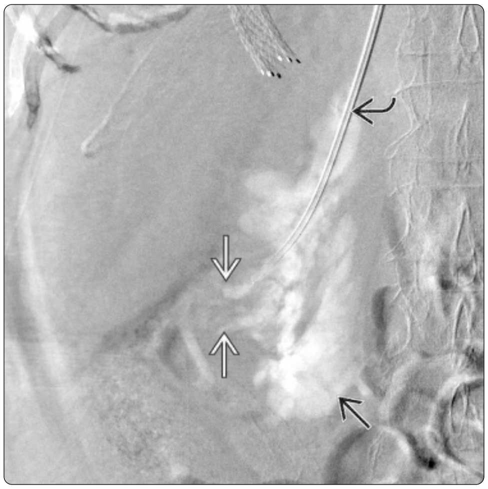


(Left) *DSA obtained with contrast injection after balloon inflation demonstrates appropriate catheter position within the RHV ➡. Efflux of contrast proximal to the balloon ➦ is seen due to incomplete occlusion, which will reduce accuracy of wedged hepatic venous pressure measurement.* **(Right)** *A curved guide sheath ➦ is rotated to direct the needle anteriorly within the RHV. The biopsy needle ➡ is advanced into liver parenchyma and firing mechanism is activated to acquire tissue.*

Transjugular Renal Biopsy (CO_2 Renal Venography)



Transjugular Renal Biopsy (Capsular Perforation)



(Left) *Following transjugular access, CO_2 DSA confirms appropriate catheter ↪ position in the right renal vein ⇨. Intrarenal veins are also seen ➡.* **(Right)** *Postbiopsy renal CO_2 venography via a 5-Fr catheter ↪ shows normal venous branches ➡ but also demonstrates a CO_2 collection ⇨ in the soft tissues along the lower renal pole, diagnostic of capsular perforation.*

TIPS

KEY FACTS

TERMINOLOGY

- Percutaneously created connection within liver between portal and systemic circulations
  - Treats portal hypertension and its complications

PREPROCEDURE

- Indications: Variceal hemorrhage, refractory ascites, Budd-Chiari
- Contraindications: Heart failure, liver failure, portal vein thrombosis, pulmonary hypertension, among others
- Review available imaging to help plan procedure

PROCEDURE

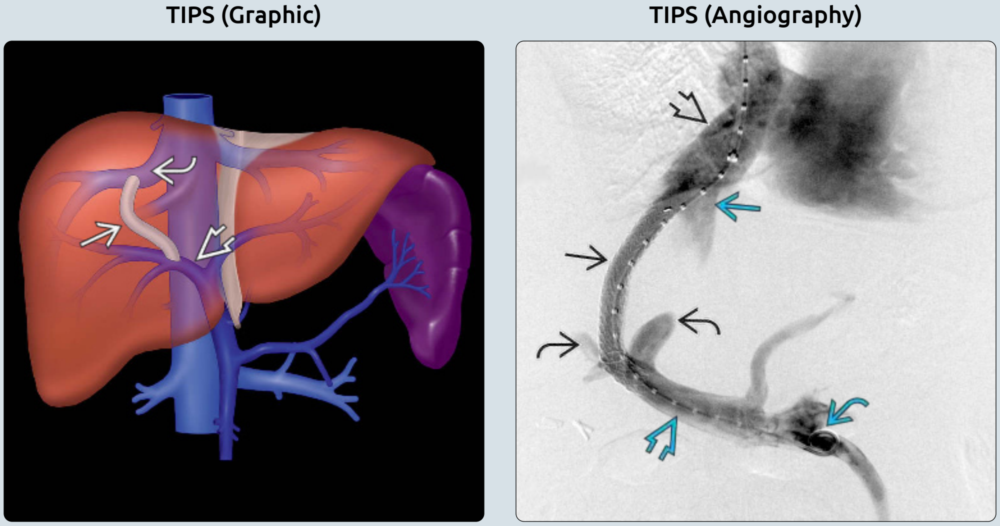
- Intrahepatic shunt placed from right hepatic vein to right portal vein (typically)
  - Entry into right portal vein at least 1 cm from bifurcation of portal vein is optimal
- Proper stent selection and placement crucial
  - Viatorr TIPS endoprosthesis is preferred stent
- May embolize/sclerose persistent varices identified on post-TIPS portography

POST-PROCEDURE

- Recommend surveillance ultrasound at 1, 3, 6, and 12 months, then every 6-12 months after
- TIPS venography, pressure measurements performed in setting of clinical or imaging evidence of restenosis
- If stenosis or occlusion occurs, may recanalize TIPS with percutaneous transluminal angioplasty/stent placement
- May also perform TIPS reduction or occlusion if necessary

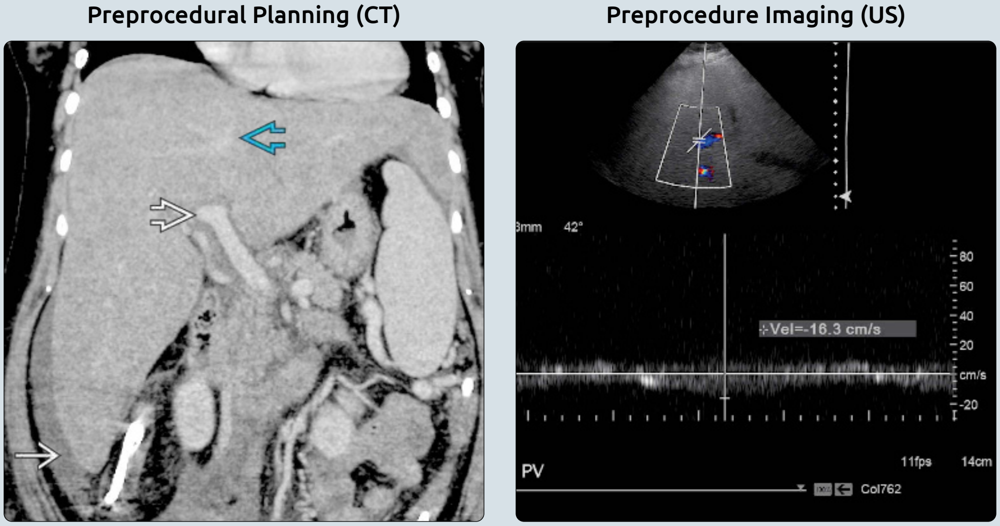
OUTCOMES

- TIPS controls variceal bleeding in ~ 90%
- Improved control of ascites in 60-85% of cases
- Early occlusion related to technical failure
- Late TIPS failure related to pseudointimal hyperplasia within stent, intimal hyperplasia within hepatic vein


TIPS (Graphic)

TIPS (Angiography)

(Left) *Graphic of a transjugular intrahepatic portosystemic shunt (TIPS) is shown. Covered stent* ➡ *serves as conduit from right portal vein* ➡ *to right hepatic vein* ➡*. Right portal vein is typically anterior and inferior to right hepatic vein.* **(Right)** *Digital subtraction angiography (DSA) after TIPS shows that contrast injected via a pigtail catheter* ↗ *flows from the portal vein* ⇨ *through the Viatorr stent graft* ⇨ *into the inferior vena cava (IVC)* ⇨ *and right atrium* ⇨ *with trace filling of the right and left portal veins* ↗*.*


Preprocedural Planning (CT)

Preprocedure Imaging (US)

(Left) *Coronal CT reformation (portal venous phase) shows relative positions of portal* ➡ *and hepatic* ⇨ *veins. Review of relationship in multiple planes can be helpful to plan TIPS procedure. Ascites* ➡ *is also noted.* **(Right)** *Color Doppler US through the portal vein reveals the portal vein is patent but flow is sluggish (16.3 cm/s). This, in conjunction with splenomegaly, is consistent with portal hypertension.*

TERMINOLOGY

Abbreviations

- TIPS: Transjugular intrahepatic portosystemic shunt

Definitions

- **TIPS**: Percutaneously created connection within liver between portal and systemic circulations
  - Diverts portal blood flow into hepatic vein
    - Reduces pressure gradient between portal and systemic circulations
    - Converts hepatofugal to hepatopetal flow
    - Decompresses varices; treats portal hypertension and its complications
- **Portal hypertension**: Increased pressure gradient between portal and hepatic veins (> 10 mm Hg)
  - Portosystemic gradient = direct portal pressure - right atrial pressure
  - Hepatic vein pressure gradient = wedged hepatic vein pressure - free hepatic vein pressure
    - Estimate of portosystemic gradient
  - Results from chronic liver disease/cirrhosis; impaired drainage through hepatic sinusoids
    - Causes of chronic liver disease/cirrhosis
      - Chronic alcohol abuse
      - Hepatitis B and C
      - Primary and secondary biliary cirrhosis
      - Budd-Chiari syndrome
      - Hemochromatosis
  - Alternative venous drainage from portal to systemic veins occurs due to chronic portal pressure elevation
    - Esophageal varices most common
      - Seen in 40% of cirrhotic patients at diagnosis
    - Gastric varices usually occur later in disease
      - ~ 20% incidence
    - Mesenteric varices also may occur
    - Stomal varices may occur in ostomy patients
    - Variceal hemorrhage major cause of death in portal hypertension

PREPROCEDURE

Indications

- Variceal hemorrhage
  - Massive uncontrollable variceal hemorrhage (rescue therapy)
  - Acute variceal bleeding refractory to endoscopic management
    - Endoscopic banding/sclerotherapy typically initial treatment for esophageal varices
      - Controls acute bleeding in 80-90%
      - More difficult with gastric/mesenteric varices
  - Variceal decompression to prevent recurrent bleeding
    - High-risk markers for rebleeding
      - Persistent large varices despite endoscopic therapy
      - Hepatic vein pressure gradient > 12 mm Hg
- Portal hypertensive gastropathy
- Refractory ascites or hepatic hydrothorax
  - Not controlled by medical therapy
  - Requiring repeated paracentesis or thoracentesis
    - Repeated paracentesis increases risk of spontaneous bacterial peritonitis
- Budd-Chiari syndrome
  - Outflow obstruction of hepatic veins
    - May be thrombotic/stenotic in origin
      - Classically intrahepatic venous thrombosis
    - Treatment based on presentation/symptoms
      - Ascites/pain/abnormal liver function tests
    - TIPS provides symptomatic control/improved hepatic function
      - Decompresses portal vein via alternate drainage pathway around occluded hepatic veins
      - Improves both fulminant and subacute disease
    - Higher risk of TIPS stenosis/thrombosis compared with other patients undergoing TIPS
- Other possible indications (no proven benefit in controlled trials)
  - Hepatorenal or hepatopulmonary syndrome
  - Sinusoidal obstruction syndrome
- TIPS method of access can be used for portal/mesenteric vein intervention
  - Thrombolysis, angioplasty, stenting, embolization

Contraindications

- No definitive absolute contraindications
- Relative contraindications
  - Heart failure
    - Elevated right or left heart pressures
  - Pulmonary hypertension
  - Rapidly progressive liver failure
  - Hepatic encephalopathy (HE)
  - Portal vein thrombosis
  - Sepsis or ongoing infection
    - Risk of TIPS stent colonization
  - Hepatic tumors
  - Coagulopathy
  - Biliary obstruction
  - Polycystic liver disease
  - Elevated model for end-stage liver disease (MELD) score
    - MELD score of > 24 associated with 30-day mortality of 60%

Alternative Procedures and Therapies

- Radiologic
  - Direct intrahepatic portosystemic shunt (DIPS)
    - Shunt directly between inferior vena cava (IVC) and portal vein
    - Intravascular ultrasound (IVUS) used to visualize and cannulate portal vein from IVC through caudate lobe
    - Potential advantages include
      - No hepatic vein stenosis
      - Decreased procedure time/radiation
      - May be only option in Budd-Chiari due to hepatic vein thrombosis
  - Balloon-occluded retrograde transvenous obliteration (BRTO)
    - May be indicated in patients with
      - Isolated gastric varices
      - Predicted poor outcome from TIPS
  - Transhepatic transportal injection of sclerosant ± coiling of varices

- Surgical
  - Portosystemic shunt creation
    - Various shunts can be created
      - Portocaval
      - Mesocaval
      - Splenorenal
    - Very effective for decompressing varices
    - Can be difficult in emergent variceal bleeding
    - Higher incidence of encephalopathy
    - Endoscopic/Interventional radiology management preferred
- Other
  - Medical management
    - Reduction of portal/splanchnic blood flow
      - Octreotide: Vasoconstrictor for acute therapy
      - Propranolol: β blocker for long-term control
    - Reduction of hepatic sinusoidal resistance
      - Isosorbide mononitrate: Equivocal effectiveness
  - Endoscopic treatment
    - Banding/sclerotherapy typically initial treatment for esophageal varices
      - High success rate

Pre-Procedure Imaging

- Abdominal US
  - Confirms portal vein patency
  - Color Doppler US evaluates direction of portal flow
    - Hepatopetal vs. hepatofugal flow
  - Demonstrates any ascites
- Cross-sectional imaging: CT or MR
  - Confirms portal vein patency
  - Evaluates for competing portosystemic shunts
    - Spontaneous splenorenal shunt
    - Mesenteric venous shunts
  - Demonstrates location/extent of varices
  - Demonstrates anatomic relationships between portal/hepatic veins
    - Puncture trajectory from hepatic to portal vein
    - Evaluates for variant anatomy
    - Evaluates for extrahepatic portal venous division into right/left portal veins
      - If needle enters portal vein outside liver parenchyma, risk of intraperitoneal hemorrhage

Getting Started

- Things to check
  - Laboratory parameters
    - Complete metabolic panel
      - Normal creatinine and glomerular filtration rate > 60
      - Liver function tests
      - Sodium, creatinine, bilirubin, and international normalized ratio (INR) used to calculate MELD
    - Complete blood count
      - Platelets > 50,000 mm^3
    - Coagulation profile
      - May be abnormal due to intrinsic liver disease
      - Prefer INR < 1.5
  - Appropriate resuscitation with fluid, blood products
    - Platelet transfusion to maintain > 50,000 mm^3
    - Fresh frozen plasma to keep INR < 1.5
  - Review all pertinent imaging
    - If ascites is present, paracentesis should be considered
- Medications
  - Hold medications based upon "moderate risk of bleeding" per Society of Interventional Radiology guidelines
    - Ticlodipine: Withhold for 7 days prior to procedure
    - Dabigatran and Fondaparinux: Withhold 2-3 days (or 3-5 days if CrCl <50 mL/min)
    - Clopidigrel: 5 days
    - Low molecular weight heparin: 12 hours
    - Aspirin: Do not withhold
  - Prophylactic broad-spectrum antibiotics
- Equipment list
  - Proprietary TIPS sets; contain access sheaths, catheters, wires, intrahepatic puncture needle
    - Haskal transjugular liver access set (Cook Medical; Bloomington, IN)
      - 16-g Ross modified Colapinto needle
    - Rösch-Uchida transjugular liver access set (Cook Medical; Bloomington, IN)
      - 0.038" trocar stylet within 5-Fr catheter; introduced via 14-g cannula/10-Fr catheter
    - Ring transjugular liver access set (Cook Medical; Bloomington, IN)
      - Ross modified Colapinto needle introduced via either 7- or 9-Fr catheter
    - Transjugular access set (AngioDynamics; Queensbury, NY)
      - 21-g puncture needle inside 5-Fr catheter; introduced via 14-g modified blunt Ross needle
  - Guidewires
    - Glidewire, Amplatz, Bentson
  - Catheters
    - Balloon occlusion catheter
    - 5-Fr multipurpose angled (MPA), Cobra, Davis, straight, calibrated (marker) pigtail
  - Angioplasty balloons
    - Predilatation: 6- to 8-mm diameter x 40 mm long
    - Postdilatation: 10- to 12-mm diameter x 40 mm long
  - Stents
    - Viatorr TIPS endoprosthesis (W. L. Gore and Associates; Newark, DE): Expanded polytetrafluoroethylene-covered stent
      - Supported by self-expanding nitinol
      - Distal 2-cm noncovered stent segment anchors device in portal vein
      - Noncovered portion allows perfusion of both right and left portal veins
      - Polytetrafluoroethylene graft lining reduces bile/mucin permeation/tissue ingrowth; improves patency
      - Bare portion placed in portal vein; covered portion in intrahepatic tract/hepatic vein
      - FDA approved for portal hypertension treatment
    - Viatorr endoprosthesis has largely replaced use of other covered and bare metal stents
      - Better patency rates
      - Reduced intimal hyperplasia

- Digital subtraction angiography (DSA) equipment with CO_2 imaging capability
- Pressure monitoring equipment

PROCEDURE

Patient Position/Location

- Best procedure approach
    - Right hepatic to right portal vein preferred for TIPS
    - Other approaches often required; influenced by anatomic variants/hepatic or portal vein occlusion
        - Middle hepatic to right portal vein
        - Left hepatic to left portal vein
- Place patient in supine position on fluoroscopy table and prep for right internal jugular vein access
- Perform with conscious sedation/general anesthesia
- Pre-TIPS paracentesis to decompress abdomen
    - Liver relocates to more anatomic position, facilitating procedure

Procedure Steps

- **TIPS creation**
- Access internal jugular vein using US
    - Right internal jugular vein preferred
- Selectively catheterize right hepatic vein
    - 5-Fr MPA or Cobra catheter
    - Inject contrast to confirm catheter position
    - May obtain lateral projection to confirm position in right hepatic vein
    - Can also catheterize middle hepatic vein
- Advance TIPS sheath over stiff wire into hepatic vein
- Obtain free hepatic vein pressure and wedged hepatic vein pressure
    - Wedge 5-Fr MPA catheter in distal hepatic vein
    - May also use balloon occlusion catheter more centrally
- Perform wedged CO_2 portography
    - Manually inject 40-50 mL of CO_2 with DSA imaging
        - Inject through wedged catheter or inflated balloon occlusion catheter
        - Visualizes portal vein; provides target for puncture
        - Prime catheter to get fluid out
    - Some experts advocate against use of CO_2 portography due to risk of capsular rupture
- Remove catheter or deflated balloon catheter over stiff guidewire
- Introduce angled TIPS cannula over guidewire
    - Advance TIPS cannula into hepatic vein
    - Remove stiff guidewire
- Puncture parenchymal tract with needle or trocar/catheter assembly
    - With cannula in proximal hepatic vein, direct puncture toward right portal vein
        - Direct cannula anteriorly and inferiorly if within right hepatic vein
        - Direct cannula posteriorly and inferiorly if within middle hepatic vein
- Attach syringe to catheter/needle hub
    - Slowly withdraw needle/catheter along tract while aspirating
- If blood aspirated, inject contrast; evaluate needle/catheter tip
    - Tip in portal vein branch vs. hepatic vein
- Portal vein access most difficult part of procedure
    - Repeat passes often required
    - Portal bifurcation may be extrahepatic
        - Puncture through liver capsule/extrahepatic puncture can cause life-threatening hemorrhage
    - Puncture of peripheral portal venous branch can create angle too acute for successful TIPS placement
    - Optimal intrahepatic portal vein access site
        - Right portal vein at least 1 cm from main portal vein bifurcation
    - Methods to evaluate portal vein location
        - CO_2 portography
            - May also be done in lateral projection
        - Review available cross-sectional imaging
        - Percutaneous placement of wire/pigtail catheter into portal vein can be used as guide
        - CT-guided placement of clip near portal confluence
        - Intracardiac echo for direct
- Advance hydrophilic guidewire (e.g., Terumo Glidewire) through cannula into portal vein
- Remove TIPS cannula over guidewire
- Introduce catheter (e.g., straight hydrophilic catheter) into portal vein
- Exchange hydrophilic catheter for calibrated pigtail catheter over stiff guidewire
- Perform direct portal venography and pressure measurements (portosystemic gradient) using calibrated pigtail catheter
    - Simultaneous hand injection through sheath
        - Identify hepatic vein/IVC junction
        - Demarcate ends of parenchymal tract
    - Markers on pigtail catheter will be used to determine appropriate stent length
- Predilated parenchymal tract using high-pressure 4- to 8-mm diameter angioplasty balloon
    - Sites of "waist" formation on balloon good indicators of portal/hepatic vein ends of tract
- Replace angioplasty catheter with 10-Fr sheath introducer
    - Advance sheath over stiff guidewire wire through tract
    - Position 10-Fr sheath tip in main portal vein
        - Advance well beyond portal vein puncture site
- Select appropriate diameter/length Viatorr stent
    - Proper stent selection/placement crucial
        - Determine appropriate Viatorr length using calibrated pigtail catheter portogram
            - Covered portion should extend from portal vein entry site to hepatic vein/IVC junction
            - 2-cm uncovered portion in portal vein
        - Stent will shorten as deployed
        - Should have smooth and gentle curve
- Introduce Viatorr into 10-Fr sheath
- Deploy Viatorr TIPS endoprosthesis
    - Unsheathe uncovered portion in main portal vein
        - Radiopaque ring at uncovered/covered junction
    - Pull back sheath and partially deployed stent to portal vein entry site
        - Will feel resistance when uncovered stent abuts portal vein margin of intrahepatic tract

  - Unsheathe and release covered portion within intrahepatic tract
- Remove Viatorr delivery system over guidewire
- Introduce high-pressure 6- to 10-mm angioplasty balloon
  - Perform poststent deployment angioplasty
- Exchange angioplasty balloon for pigtail catheter
  - Perform post-TIPS DSA portography
- Obtain post-TIPS pressure measurements
  - Document portal/hepatic vein/IVC pressures
  - Determine post-TIPS pressure gradient
    - Record all pressures in medical record/report
- If satisfactory images/pressures, remove wires/catheters
- Remove jugular vein access sheath
  - May delay removal until recovery from anesthesia
- Obtain venous hemostasis with manual compression
  - May be helpful to elevate head of bed
    - Decreases venous pressure at access site
- **Variceal embolization via TIPS**
  - Persistent varices may be identified on post-TIPS portography
    - May arise from coronary, splenic, superior/inferior mesenteric veins
    - Thin walled and can spontaneously rupture
  - Large competing shunt can divert flow from TIPS
    - Shunts may decrease portosystemic gradient
    - Embolization may improve TIPS patency
    - Embolization may also decrease HE
  - May be embolized with coils, Amplatzer plugs, sclerosants, liquid embolics
  - Can treat during TIPS procedure or stage
- **TIPS revision**
  - **Indication**
    - Correction of malfunctioning TIPS
      - Recurrence of ascites
      - Treatment of stenosis/occlusion/thrombosis
      - Do not wait for recurrence of variceal bleeding
  - **Etiology**
    - Early occlusion related to technical failure
      - Acutely angled shunt trajectory
      - Inadequate stent length
    - Late TIPS failure due to in-stent pseudointimal hyperplasia/hepatic vein intimal hyperplasia
  - **Technique**
    - Access right internal jugular vein using US
    - Selectively catheterize hepatic end of TIPS
      - Use MPA catheter/hydrophilic guidewire
    - Cross stenosis/occlusion with guidewire/catheter
      - Obtain appropriate DSA imaging
    - Recanalize TIPS with percutaneous transluminal angioplasty/repeat stent placement
      - May use noncovered stent inside original stent
      - If stenosis thought due to exposed parenchymal tract, then revise with covered stent
  - **Results**
    - Improves long-term patency rates
      - 1-year primary patency (66%); 2-year primary patency (42%)
      - 1-year primary-assisted patency (83%); 2-year primary-assisted patency (79%)
      - 1-year secondary patency (96%); 2-year secondary patency (90%)
- **TIPS reduction**
  - **Indication**
    - Overly effective TIPS may cause liver failure/refractory encephalopathy
      - Goal is to decrease/occlude flow through shunt
  - **Technique (parallel stent method)**
    - Access right internal jugular vein using US
      - Place large-bore (12-Fr) sheath
    - Select TIPS with catheter/guidewire
      - Use 5-Fr selective catheters (e.g., MPA)
    - Advance 10-Fr long sheath into TIPS through 12-Fr sheath
    - Advance 2 guidewires through TIPS into portal vein
    - Introduce balloon-mounted bare-metal stent over single wire
      - Nominal diameter of stent between 4-6 mm
      - Position within midportion of covered section of TIPS
      - Do not inflate balloon or deploy stent
    - Introduce self-expanding covered stent over other guidewire
      - Covered stent should be at least 2 cm longer that balloon-mounted stent
    - Position adjacent to balloon-mounted stent
    - Deploy covered stent inside of TIPS
      - Remove covered stent delivery system
      - Advance pigtail catheter into portal vein beyond new covered stent; remove guidewire
    - Obtain pressure measurements via pigtail catheter and sheath
    - Slowly inflate balloon-mounted stent while recording pressures
      - Balloon-mounted stent will narrow adjacent newly deployed covered stent
    - When desired gradient measurement achieved, stop inflating balloon-mounted stent
    - Deflate and remove balloon and guidewires, leaving both stents in position
    - Remove jugular access sheath
    - Obtain hemostasis with manual compression
  - **TIPS reversal (occlusion) technique**
    - Cannulate TIPS with catheter/guidewire
    - Place embolization coils/plug occluder in TIPS
    - May inflate balloon in TIPS for 12-48 hours for temporary occlusion
      - If symptoms resolve, then proceed to permanent occlusion

POST PROCEDURE

Expected Outcome

- Standardized procedure with high success rate (95%)
- Variceal bleeding controlled in ~ 90% of cases
- Improved control of ascites in 60-85% of cases
  - New or worsened encephalopathy in 25-30%
- Failure of TIPS usually from anatomy that prevents acceptable portal venous puncture
- Mortality rates
  - Early (17-27%); 1 year (30-45%); 5 year (50-70%)

  - Most deaths due to liver failure and sepsis
  - Patients treated for ascites have lowest survival rates
    - More severe underlying liver disease
  - MELD score can predict post-TIPS mortality
    - MELD score and 30-day mortality
      - MELD score 1-10 (3.7%)
      - MELD score > 24 (60%)

Things To Do

- In emergent or urgent TIPS, continue preprocedural resuscitation
- Monitor for immediate periprocedural complications
- Imaging surveillance
  - Recommend Doppler US at 1, 3, 6, and 12 months after TIPS creation and every 6-12 months thereafter
    - High sensitivity/specificity for shunt function/dysfunction reported with Doppler criteria
      - Absent flow in TIPS
      - Low peak shunt velocity (< 50-90 cm/s)
      - High peak shunt velocity (≥ 190 cm/s)
      - Low mean portal vein velocity (< 30 cm/s)
      - Return of hepatopetal flow in intrahepatic portal veins
      - Significant change in shunt velocity
  - Perform TIPS venography in setting of clinical, imaging evidence of restenosis

OUTCOMES

Problems

- Encephalopathy occurs in 25-30% of patients
  - Manifests as confusion, drowsiness, coma
  - More common in patients who have had episodes of pre-TIPS encephalopathy
  - Shunt diameter/degree of portosystemic gradient reduction relate to development of encephalopathy
  - Often can be medically treated
    - Lactulose, neomycin, Flagyl, zinc, Ucephan
  - TIPS reduction to smaller diameter/intentional TIPS thrombosis may be necessary for control
- TIPS stenosis/occlusion/thrombosis requiring revision
- Difficult TIPS may be lengthy procedure
  - Potential for excessive radiation exposure
    - Monitor for radiation dermatitis/ulceration

Complications

- Immediate/periprocedural complication(s)
  - Hemorrhage
    - Intraperitoneal hemorrhage from puncture of liver capsule/extrahepatic puncture of portal vein
    - Intraparenchymal from puncture of hepatic artery
    - Capsular rupture from forceful injection of CO_2
  - Bile duct injury
  - Acute increases in cardiac output, central venous, pulmonary wedge pressures
    - Can lead to acute pulmonary edema, congestive heart failure
    - Patients should be closely monitored after procedure until hemodynamic status stabilizes
  - Acute liver failure
- Delayed complication(s)
  - Encephalopathy
  - Progressive liver failure
  - TIPS stenosis/occlusion/thrombosis
    - Early occlusion related to technical failure
    - Late TIPS occlusion/stenosis may be caused by pseudointimal hyperplasia in stent or intimal hyperplasia adjacent to stent
  - Late recurrent hemorrhage
    - More common with ectopic varices
    - Decreased incidence with covered stent use
- Other complications
  - TIPS infection
    - Rare; reported in 1% of cases
      - Usually successfully managed with antibiotics

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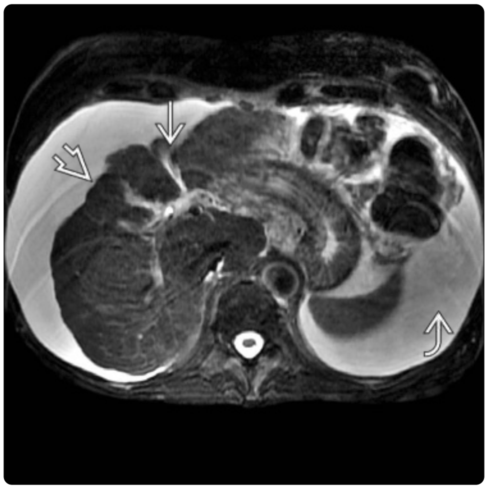
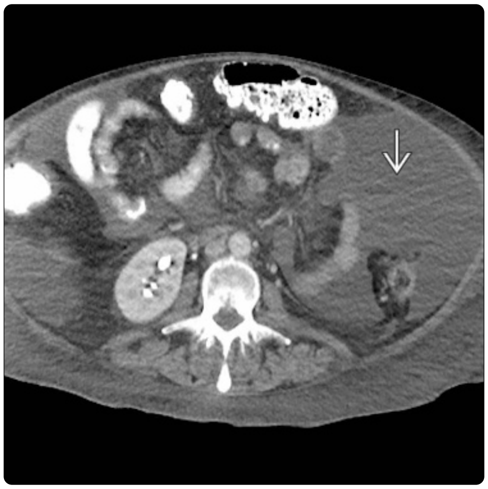
(Left) *T2-weighted axial MR of the abdomen shows marked cirrhosis of the liver with fibrosis and contraction →. Note the nodular surface ⇨ of the liver. Also noted is marked ascites ↪. Cirrhosis is the most common cause of portal hypertension.* **(Right)** *Axial CECT shows moderate ascites →. Refractory ascites or hepatic hydrothorax are 2 indications for TIPS. It is advised to drain ascites prior to procedure to return liver to more anatomic position and reduce risk of complication.*

TIPS Indications (Portal Hypertension Secondary to Cirrhosis)

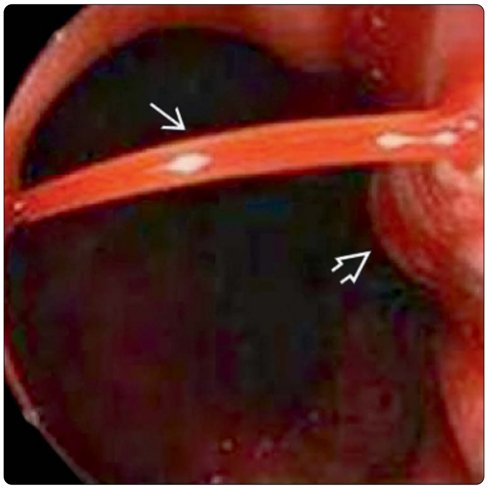


TIPS Indications (Refractory Ascites)

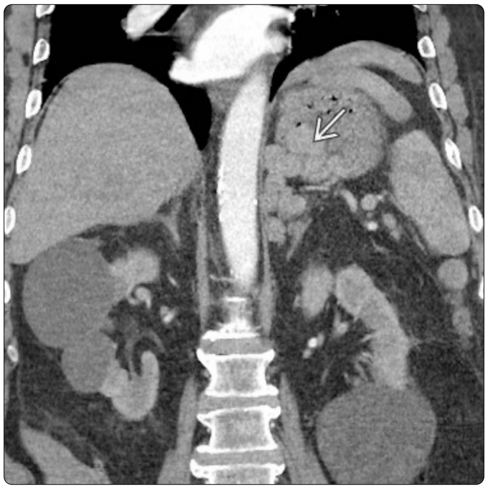


(Left) *Endoscopic image at the gastroesophageal junction demonstrates active variceal hemorrhage →. Multiple varices are also identified by prominent bulging mucosa ⇨. Recurrent hemorrhage, despite endoscopic management, is an indication for TIPS.* **(Right)** *CT coronal reformation (arterial phase) of the same patient demonstrates marked gastroesophageal varices protruding into the stomach wall →. Following successful TIPS placement, varices decompressed and bleeding ceased.*

TIPS Indications (Variceal Hemorrhage)

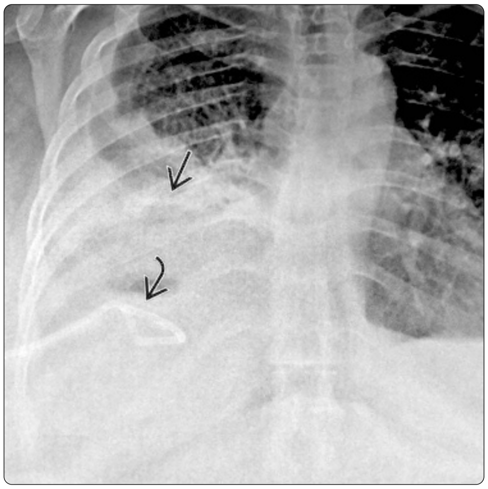


TIPS Indications (Gastroesophageal Varices)

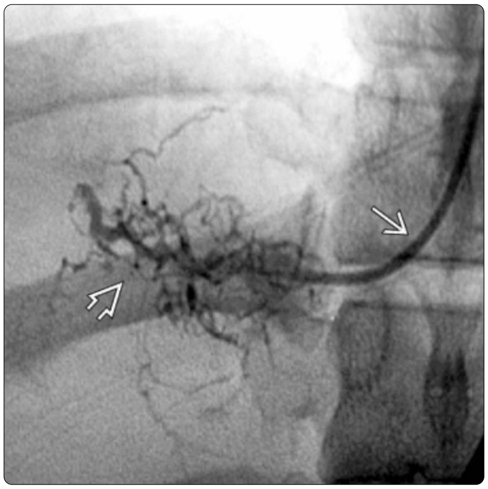


(Left) *The effusion of hepatic hydrothorax → is transudative, similar in composition to that of ascites. Chest tube ↪ placement is contraindicated in the majority of uncomplicated hydrothorax cases but acceptable for spontaneous bacterial empyema.* **(Right)** *A needle and cannula → directly punctured intraparenchymal hepatic veins. The spiderweb appearance of the hepatic vein collaterals ⇨ is consistent with Budd-Chiari. If central hepatic veins cannot be recanalized, DIPS may be the only option.*

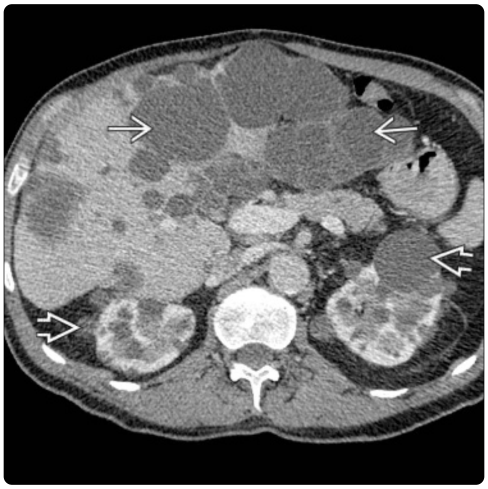
TIPS Indications (Hepatic Hydrothorax)



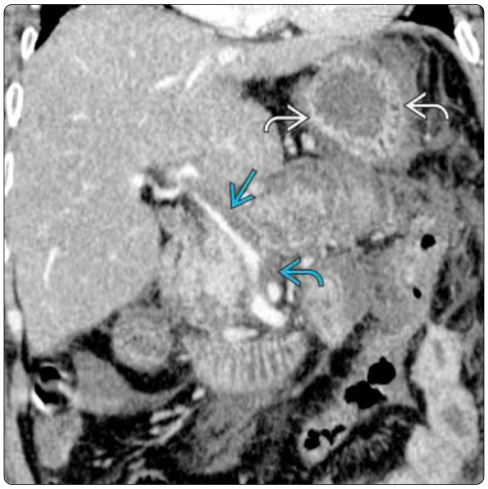
TIPS Indications (Budd-Chiari)



Relative Contraindications (Polycystic Liver Disease)

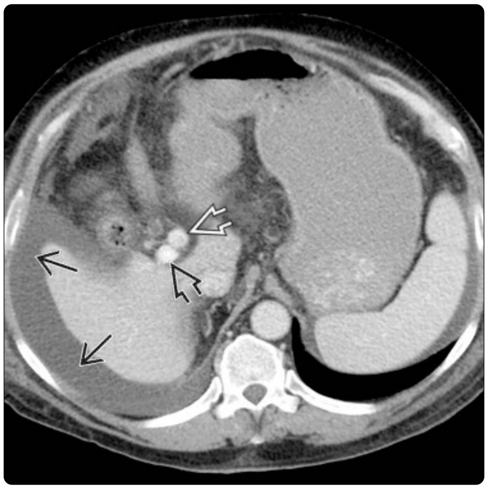


Relative Contraindications (Portal Vein Thrombus)

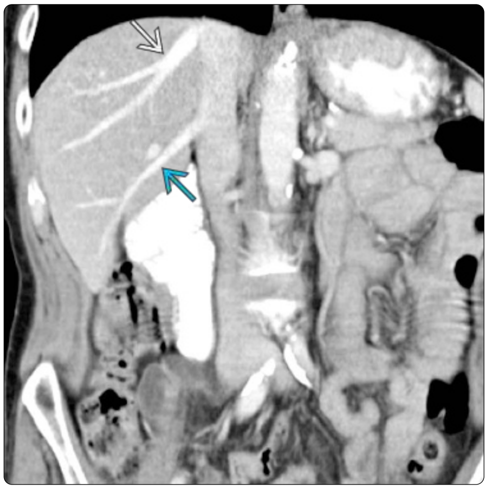


(Left) *Axial CT (portal venous phase) through the liver reveals innumerable low-density cysts of varying sizes throughout the liver* ➡ *and kidney* ➡ *consistent with polycystic liver disease. Polycystic liver disease is a relative contraindication to TIPS.* **(Right)** *CT coronal reformat (portal venous phase) shows thrombus in the portal* ⇨ *and superior mesenteric* ⇨ *veins as well as gastric varices* ➡*. Imaging suggests retrograde variceal obliteration (BRTO or variation) may be a better option than TIPS.*

Complicating Considerations (Extrahepatic Portal Bifurcation, Ascites)

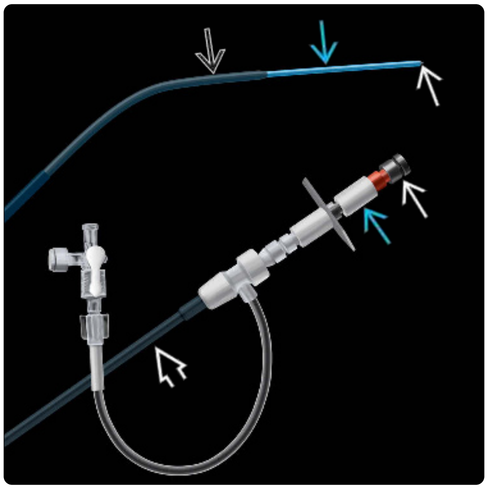


Complicating Considerations (Accessory Hepatic Vein)

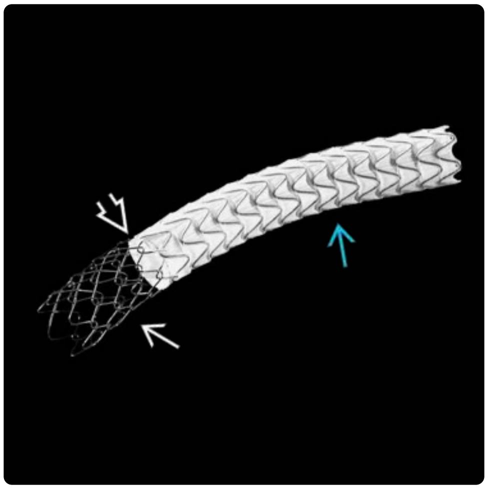


(Left) *Available imaging, such as this CECT, should be reviewed before TIPS. Ascites* ⇨ *is present, and paracentesis should be considered. The portal vein bifurcation into right* ⇨ *and left* ➡ *branches is extrahepatic. Puncture of the extrahepatic portion of the portal vein can cause life-threatening bleeding.* **(Right)** *Coronal reconstruction of a CECT in a different patient reveals an accessory right hepatic vein* ⇨*, which must not be mistaken angiographically for the main right hepatic vein* ➡ *during TIPS placement.*

Equipment (TIPS Set)



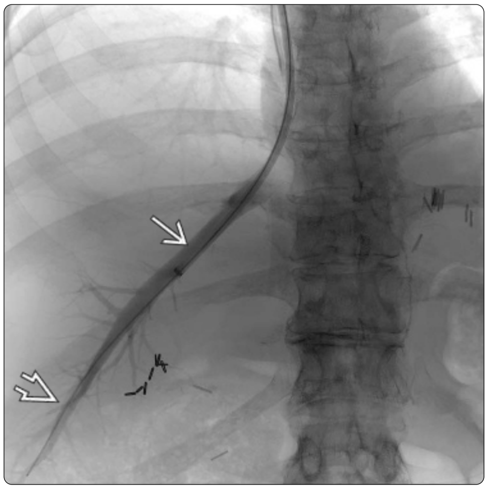
Equipment (Viatorr TIPS Endoprosthesis)



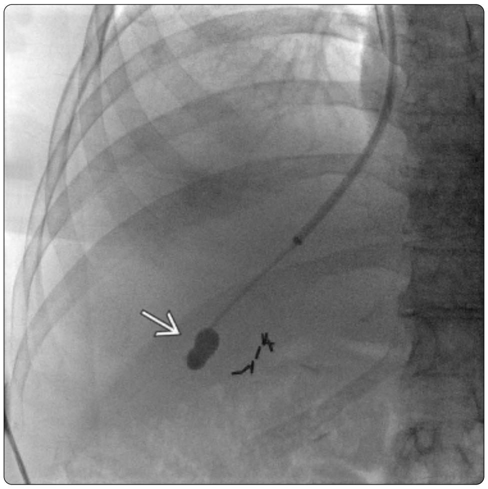
(Left) *A Cook Medical Rösch-Uchida transjugular liver access set is shown with proximal and distal ends of the assembled device. A 0.038" trocar stylet* ➡ *within 5-Fr catheter* ⇨ *is introduced via 14-g cannula* ⇨*/10-Fr sheath* ➡*.* **(Right)** *The Viatorr TIPS endoprosthesis is constructed of self-expanding nitinol. A 2-cm noncovered segment* ➡ *extends into portal vein and the ePTFE-covered segment* ⇨ *traverses the parenchymal tract into the hepatic vein. A radiodense band* ➡ *marks the junction.*

(Left) *After selecting the right hepatic vein with a guidewire and catheter, the 10-Fr sheath* ➡ *is advanced into the hepatic vein over the guidewire* ⇨*. Contrast was injected through the sheath and hepatic venogram was performed to confirm sheath location.* **(Right)** *A balloon occlusion catheter* ➡ *is advanced over the stiff guidewire into the hepatic vein. Pressures are obtained with the balloon both deflated and inflated. The gradient is an estimate of portosystemic pressure gradient.*

TIPS Procedure: Step-by-Step (Hepatic Venogram)

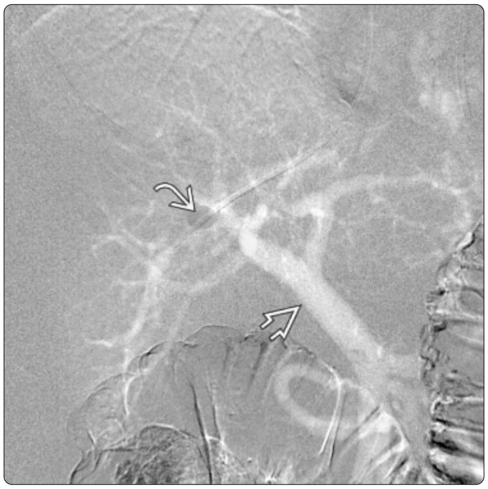


TIPS Procedure: Step-by-Step (Hepatic Vein Pressures)

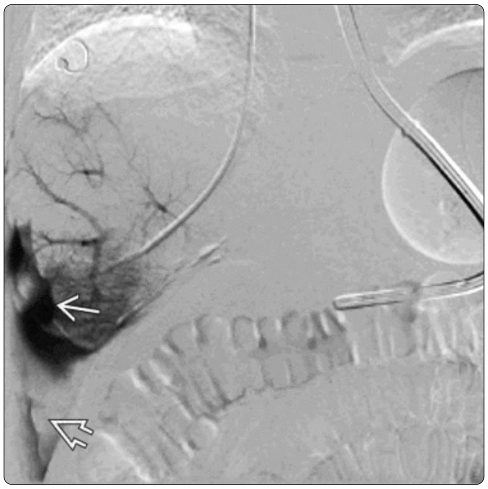


(Left) *After manometry, the balloon is inflated* ↪*, CO_2 contrast is injected, and a wedged CO_2 portogram* ⇨ *is obtained.* **(Right)** *Capsular rupture or perforation is a potential complication or TIPS direct puncture or CO_2 portography. In this case, the patient became hypotensive following CO_2 portal venogram. Wedged hepatic venogram with contrast shows capsular rupture* ➡ *with intraperitoneal extravasation* ⇨*.*

TIPS Procedure: Step-by-Step (Wedged CO_2 Portography)

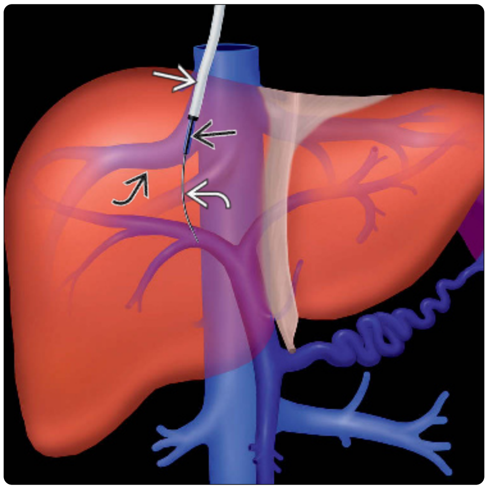


Capsular Rupture (Wedged Hepatic Venogram)

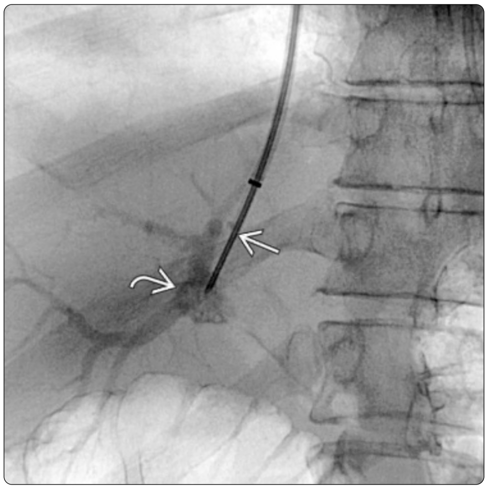


(Left) *Graphic shows the 10-Fr sheath* ➡ *in the right hepatic vein* ⇨*. The balloon occlusion catheter has been replaced with a 16-g access needle* ↪ *sheathed in a 9-Fr catheter* →*.* **(Right)** *The CO_2 portogram is now used as a reference during needle puncture of the portal vein. The angled cannula (needle)* ➡ *is directed anteriorly from the right hepatic vein and is advanced into the area of the target portal branch. The needle is withdrawn while aspirating. Upon blood return, contrast is injected via the needle to opacify the portal system* ↪*.*

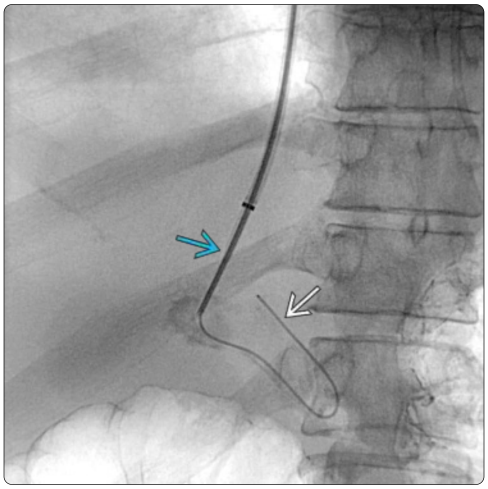
TIPS Procedure: Step-by-Step (Portal Vein Puncture)



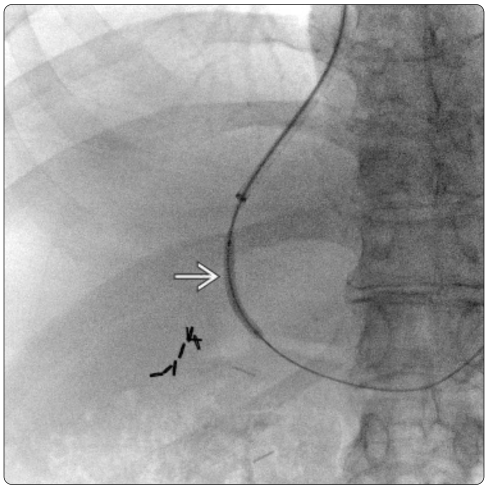
TIPS Procedure: Step-by-Step (Portal Vein Puncture)



TIPS Procedure: Step-by-Step (Portal Vein Access)

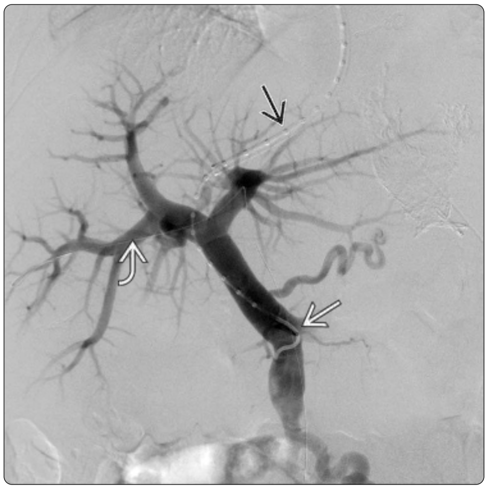


TIPS Procedure: Step-by-Step (Initial Angioplasty of Tract)

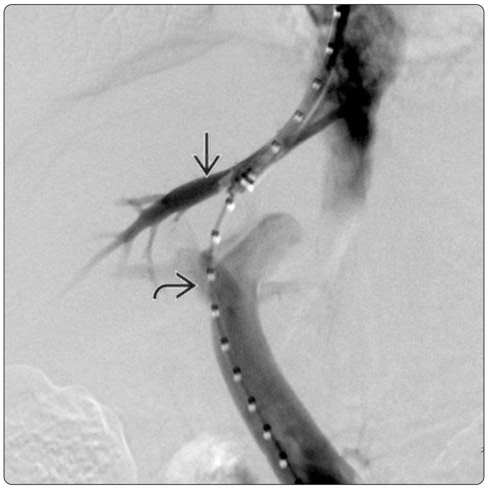


(Left) *Following successful portal vein puncture, a wire* ➡ *is advanced through the needle/cannula* ⇨ *into the portal vein.* **(Right)** *The floppy guidewire is exchanged for a stiff guidewire through a straight catheter. An optional step in patients with dense fibrosis of the liver, parenchymal tract angioplasty with a 4- or 5-Fr low-profile balloon* ➡ *may ease passage of the calibrated flush catheter across the tract into the portal vein.*

TIPS Procedure: Step-by-Step (Portal Venogram)

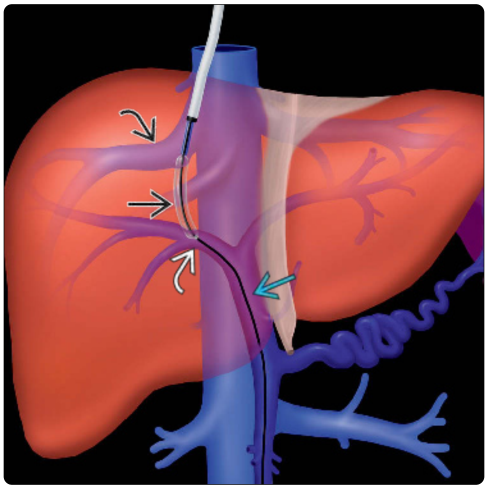


TIPS Procedure: Step-by-Step (Portal and Hepatic Venogram)

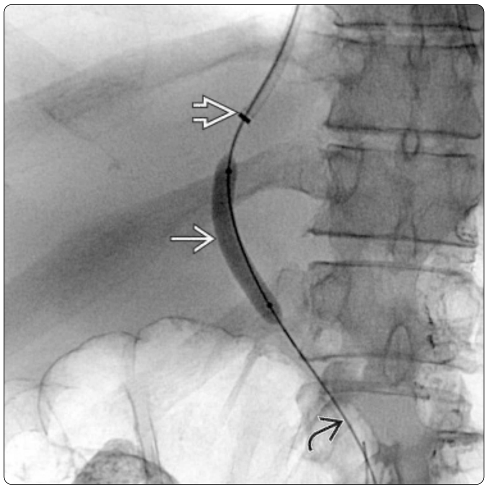


(Left) *DSA portography is performed via a calibrated flush catheter* ➡*. One-cm marks* ⇨ *on the catheter are used to determine the stent length necessary to cover the parenchymal tract. Note a percutaneous wire* ↪ *is placed into the portal veins for targeting purposes.* **(Right)** *An alternate visualization method, simultaneous contrast injection through the guidesheath and flush catheter highlights the hepatic* ⇨ *and portal* ↪ *veins. The length of the TIPS stent is subsequently determined.*

TIPS Procedure: Step-by-Step (Dilation of Tract)

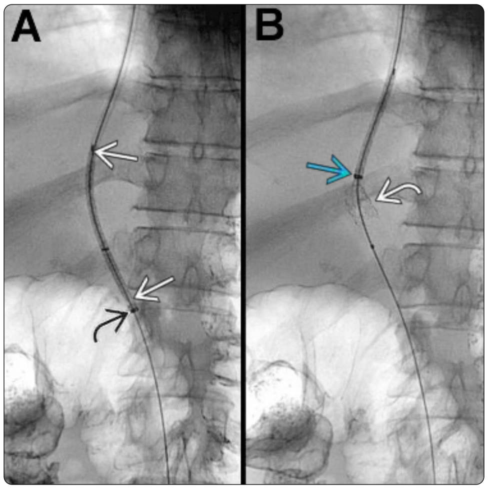


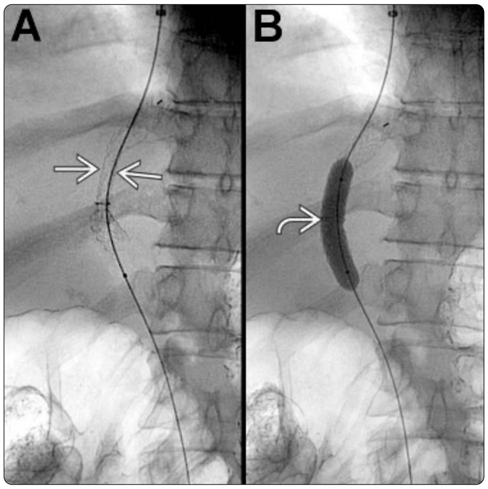
TIPS Procedure: Step-by-Step (Angioplasty of Tract)



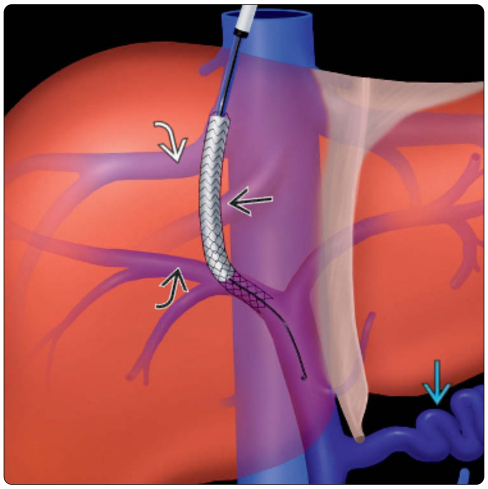
(Left) *Graphic shows dilation of the parenchymal tract between the hepatic* ↪ *and portal* ↪ *veins. Over a stiff guidewire* ⇨*, dilation is performed with a small-diameter angioplasty balloon* ⇨ *so that the sheath can be advanced through the tract into the portal vein.* **(Right)** *Radiograph shows dilatation of the TIPS tract with a 7-Fr balloon* ➡ *before Viatorr placement. The sheath tip* ⇨ *remains in the right hepatic vein, and the guidewire* ↪*, which crosses the intrahepatic tract, extends well into the portal system.*

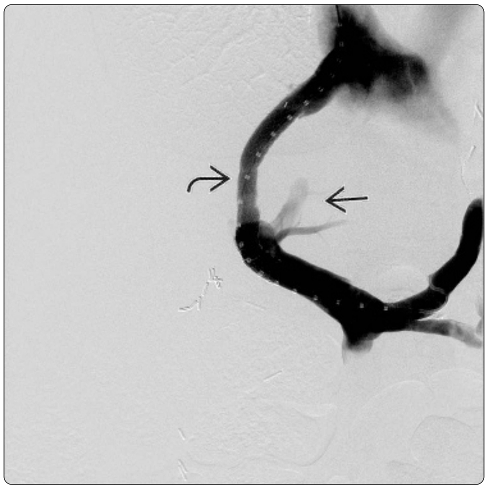
(Left) *(A) The guidesheath → is advanced into the portal vein followed by advancement of the Viatorr stent → to the sheath tip. (B) The sheath → is withdrawn, exposing the uncovered portion → of the stent, which is then withdrawn until resistance is met at the entry into the portal vein.* **(Right)** *(A) The covered portion of the stent is deployed by pulling the "rip cord." The constricted area → of the stent reflects the parenchymal tract. (B) The stent is then fully distended with a percutaneous transluminal angioplasty (PTA) balloon →.*


TIPS Procedure: Step-by-Step (Viatorr Stent Placement)

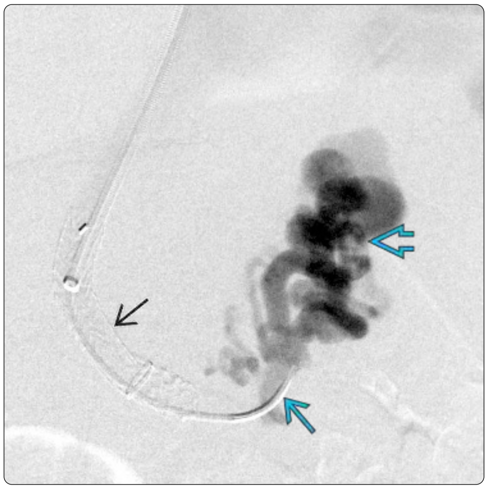

TIPS Procedure: Step-by-Step (Viatorr Stent Placement)

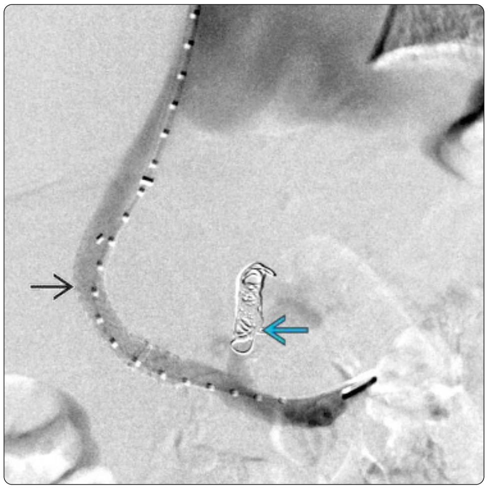
(Left) *After TIPS creation, a Viatorr stent graft → extends from the right portal vein → to the right hepatic vein →, thereby providing a conduit between the portal and systemic circulations. Note the coronary vein →.* **(Right)** *DSA portography after Viatorr deployment shows preferential flow through the shunt → and minimal opacification of the intrahepatic portal system →. Repeat manometry is performed after TIPS to document a satisfactory reduction of the portosystemic gradient.*

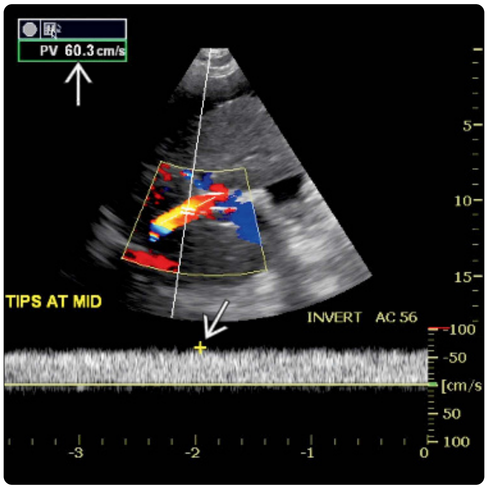

TIPS Procedure: Step-by-Step (Graphical Representation)

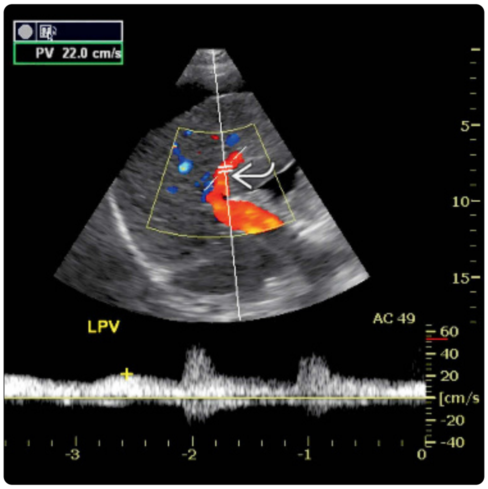

TIPS Procedure: Step-by-Step (Post TIPS Venogram)

(Left) *TIPS creation may be sufficient to decompress esophageal varices and control hemorrhage. Persistent bleeding, however, may require variceal embolization. DSA venogram shows a catheter → introduced through the TIPS → and used to selectively inject the gastroesophageal varices → that arise from the coronary vein.* **(Right)** *Following coil embolization of the coronary vein → via the TIPS →, DSA portal venography confirms successful embolization and continued TIPS patency.*

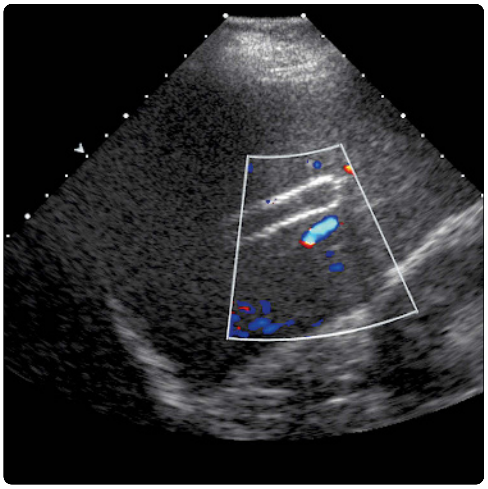

Variceal Embolization (Coronary Vein)

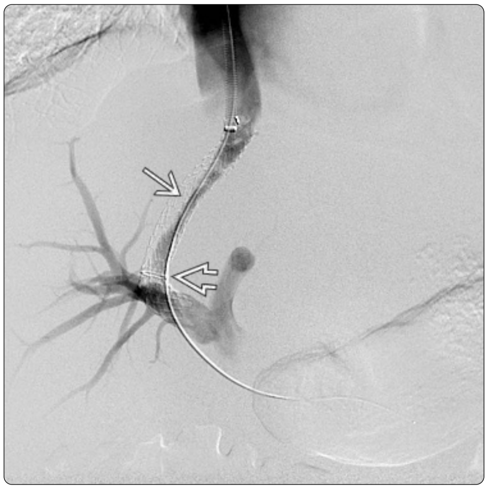

Variceal Embolization (Coronary Vein)


TIPS Surveillance (Decreased Peak Velocity)

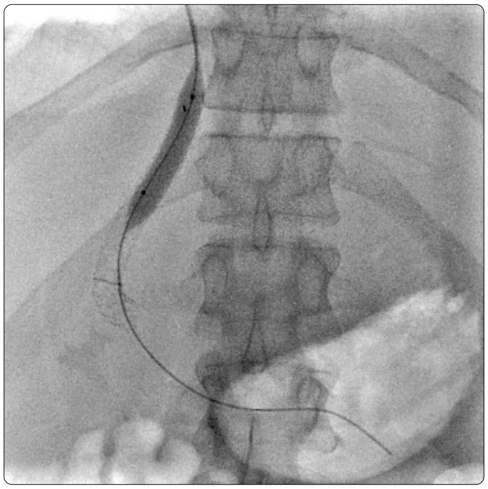

TIPS Surveillance (Left Hepatic Vein Hepatopetal Flow)

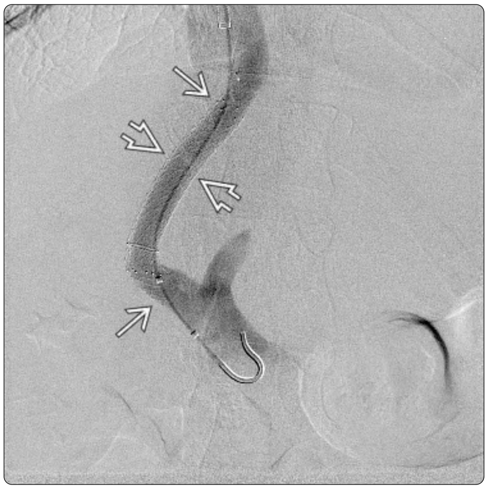
(Left) *Color Doppler US shows a midstent peak velocity of 60.3 cm/sec ➡. This is decreased from the initial post-TIPS US (120 cm/sec). When combined with the clinical scenario, Doppler US is very sensitive for detecting shunt dysfunction.* **(Right)** *Color Doppler US shows hepatopetal flow in the left portal vein ↪, which also is changed from the initial post-TIPS US. These findings suggest shunt dysfunction.*


TIPS Surveillance (Occluded Stent)


TIPS Stenosis: Uncovered Hepatic Parenchyma (Initial Venogram)

(Left) *Color Doppler US displays no flow within the TIPS stent consistent with complete occlusion. Depending on the acuity of this finding, endovascular recanalization and thrombolysis may be possible.* **(Right)** *TIPS venogram 2 weeks after placement shows marked narrowing within the TIPS ➡, likely a result of thrombosis. Note the noncovered portion of the stent appears to extend beyond the margin of the right portal vein ⇨.*

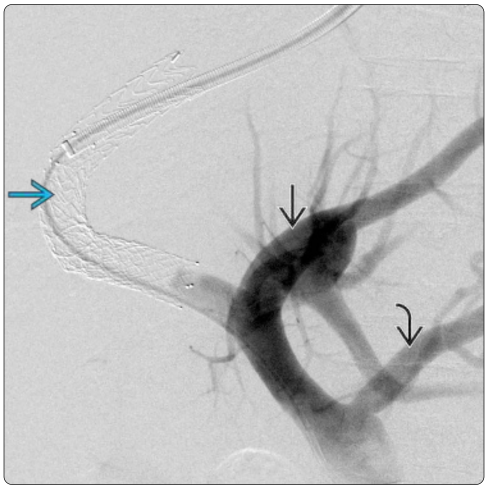

TIPS Stenosis: Uncovered Hepatic Parenchyma (Percutaneous Transluminal Angioplasty)


TIPS Stenosis: Uncovered Hepatic Parenchyma (Secondary Stent Placement)

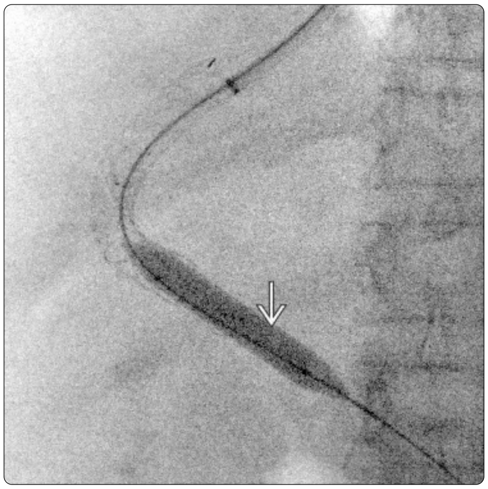
(Left) *Mechanical thrombolysis and PTA were then performed within the stent. Saved fluoroscopic image shows a balloon inflated within the Viatorr endoprosthesis. Multiple inflations were performed through the length of the stent.* **(Right)** *Finally, a 2nd covered stent ➡ was placed inside the original TIPS due to suboptimal placement of the initial Viatorr stent exposing a small portion of the parenchymal tract. TIPS is now widely patent ⇨.*

(Left) *DSA portography reveals occlusion of the TIPS ⇨. Flow is patent within the left portal vein ⇨ and coronary vein ⇨.* **(Right)** *Following administration of IV heparin, clot maceration is performed with an 8-Fr angioplasty balloon ➔. A subsequent portogram confirmed that flow was restored through the TIPS.*

TIPS Occlusion: Hepatic Venous Outflow (Initial Venogram)

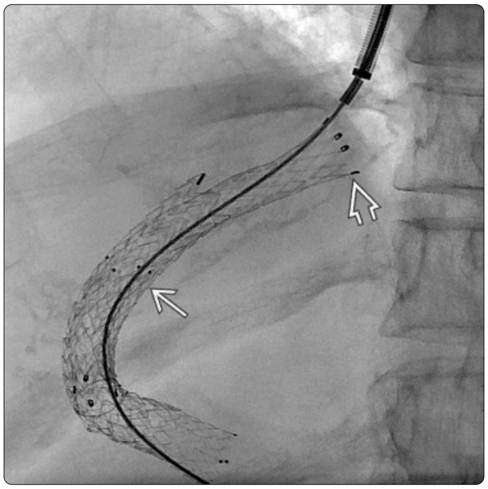


TIPS Occlusion: Hepatic Venous Outflow (Balloon Maceration of Thrombus)

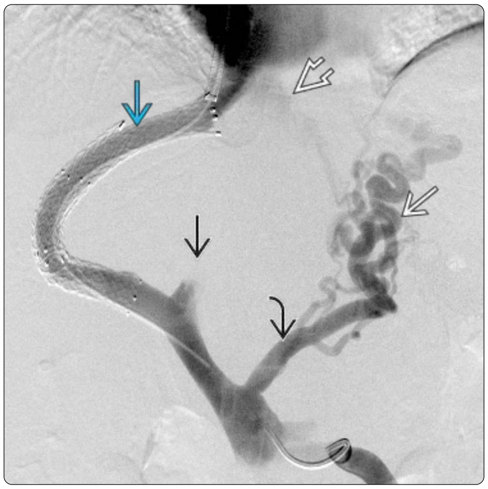


(Left) *The TIPS was extended by deploying a self-expanding covered stent from the midportion of the existing TIPS stent ➔ to the IVC-hepatic vein junction ➔.* **(Right)** *Following TIPS revision, a portogram shows patency of the TIPS ⇨ and reversal of flow in the left portal vein ⇨. Consideration should now be given to performing embolization of the patent coronary (left gastric) vein ⇨, which continues to fill gastric ➔ and esophageal ➔ varices.*

TIPS Occlusion: Hepatic Venous Outflow (Extension of Hepatic Venous Stent)

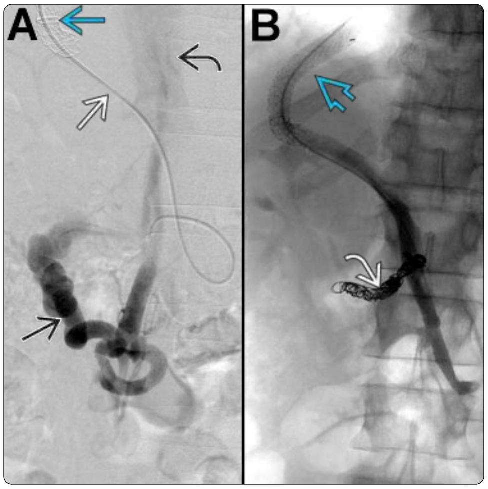


TIPS Occlusion: Hepatic Venous Outflow (Post Revision Venogram)

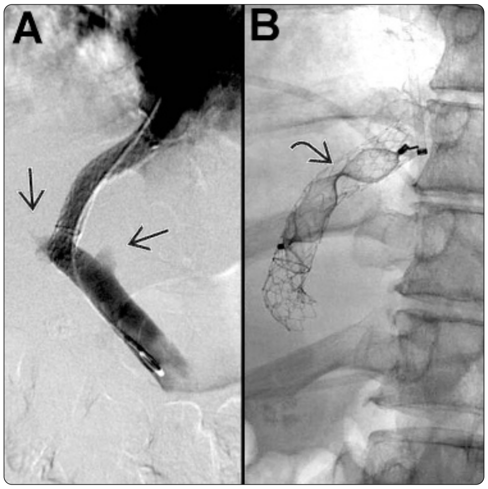


(Left) *(A) A catheter ➔ was advanced through an occluded TIPS ⇨ and into a large mesenteric varix ⇨ arising from the superior mesenteric vein, draining systemically into the IVC ⇨, and representing a competing shunt. (B) The varix was coil embolized ➔. PTA of the TIPS ⇨ restored patency.* **(Right)** *(A) DSA portography in a patient with severe hepatic encephalopathy and worsening liver function after TIPS shows minimal intrahepatic portal ⇨ filling. (B) An Amplatzer vascular plug ⇨ was used to successfully close the TIPS.*

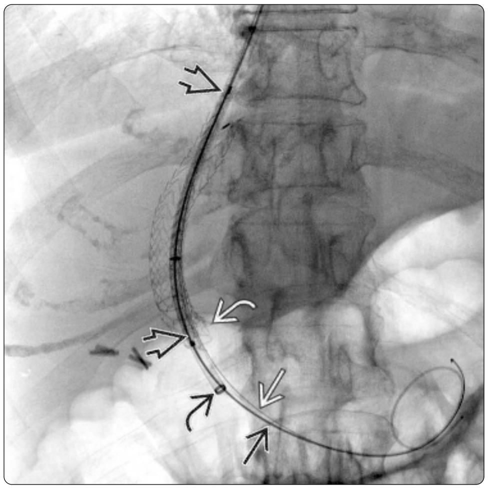
TIPS Dysfunction (Embolization of Competing Shunt)



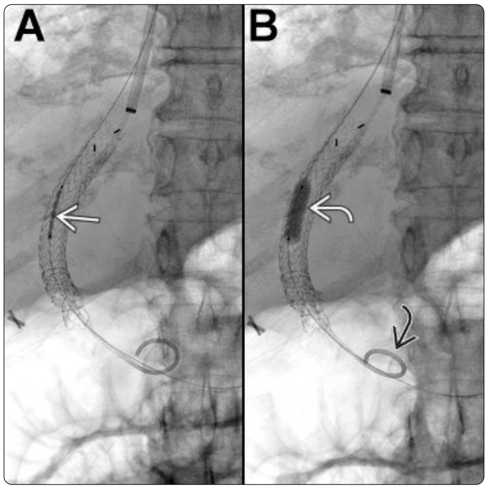
TIPS Occlusion/Reversal (Amplatzer Embolization)



TIPS Reduction: Parallel Stent Technique (Advancement of Covered Stent)

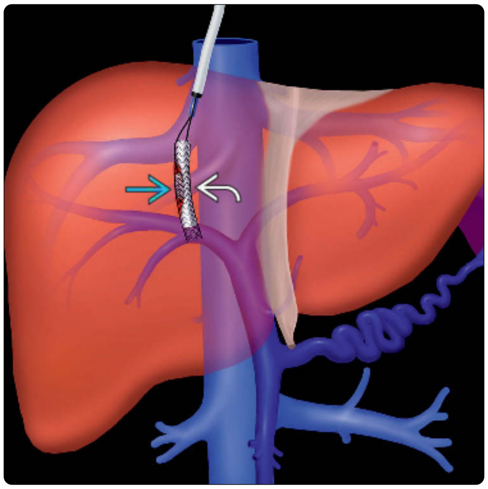


TIPS Reduction: Parallel Stent Technique (Deployment of Stent)

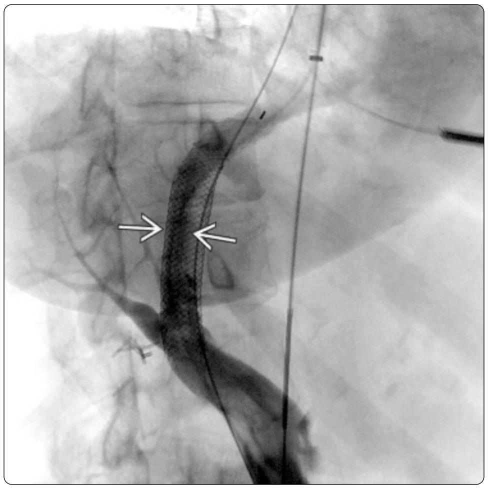


(Left) *A sheath is placed through the TIPS over a guidewire ⇨ and positioned with the tip ↷ beyond the end ⤻ of the original Viatorr. A new Viatorr ⇨ is introduced via the sheath. A 2nd parallel guidewire ➡ is also placed through the TIPS.* **(Right)** *(A) A balloon-mounted stent ➡ is placed over the 2nd guidewire and positioned inside the midportion of the original Viatorr. The 2nd Viatorr is deployed. (B) After replacing the Viatorr delivery system with a pigtail catheter ↷, the balloon-mounted stent is inflated ⤻.*

TIPS Reduction: Parallel Stent Technique (Intra-TIPS Balloon and Stent)

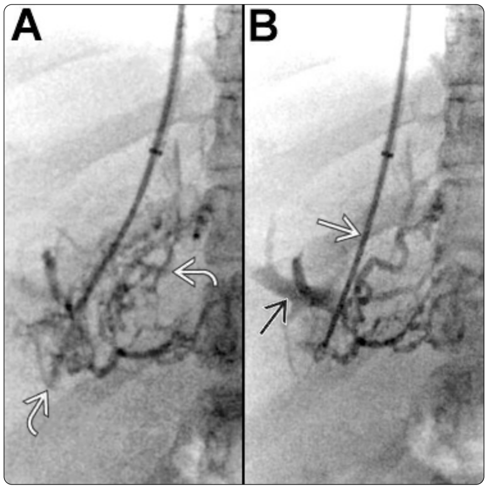


TIPS Reduction: Parallel Stent Technique (Post Revision Venogram)

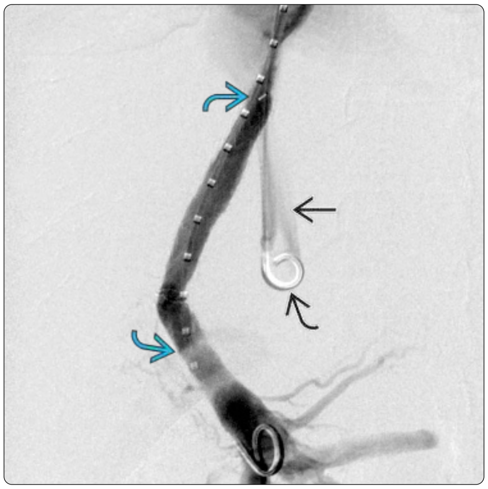


(Left) *As the balloon-mounted stent ⇨ is inflated, it narrows the "waist" ⤻ of the newly deployed Viatorr endoprosthesis, thus reducing flow through the TIPS. The new pressure gradient is then measured across the narrowed channel.* **(Right)** *After balloon-mounted stent deployment, the balloon is deflated and removed, leaving the stent in place. Completion venogram shows the narrowed "waist" ➡ of the TIPS reduction.*

DIPS Shunt: Direct IVC to Portal Shunt (Sharp Portal Venous Access)



DIPS Shunt: Direct IVC to Portal Shunt (Post DIPS Venogram)



(Left) *(A) DIPS is an alternative to TIPS for patients with occluded hepatic veins and spiderweb-like hepatic venous collaterals ⤻, (e.g., Budd-Chiari). (B) Note direct needle puncture ➡ from the IVC to the liver; contrast injection opacifies portal branches ⇨.* *Intravascular US may be used to guide puncture from the IVC to the caudate lobe.* **(Right)** *After portal vein opacification and access, the procedure steps are similar to TIPS. A Viatorr ↷ courses from the portal vein to the IVC ⇨, which is partially opacified by the pigtail catheter ↷.*

Balloon Occlusion Variceal Ablation

KEY FACTS

TERMINOLOGY

- **Balloon-occluded retrograde transvenous obliteration (BRTO)**
  - Sclerosant thrombosis of gastric varices (GV)
  - BRTO vs. TIPS
    - BRTO: Flow redirected to liver, potentially improving hepatic encephalopathy and preserving liver function (6-9 months), but aggravating portal hypertension and potentially worsening esophageal varices
    - TIPS: Flow directed away from liver can result in worsening of encephalopathy and liver failure, especially if model for end-stage liver disease > 19
- **GV**
  - GV bleeding mortality > esophageal varices
  - Endoscopic treatment difficult, large varices/high flow
  - Associated with portosystemic shunt
- **Spontaneous portosystemic shunt (SPS)**
  - Often due to high portal pressure; rarely due to obstruction of portal venous system
  - Afferent veins of SPS (portal inflow): Left gastric, short gastric, posterior gastric
  - Efferent veins of SPS (systemic outflow): Gastrorenal, inferior phrenic

PROCEDURE

- Catheterize gastrorenal shunt and perform balloon occlusion venography
- Selectively catheterize and occlude collaterals
- Inject sclerosant with balloon occluded

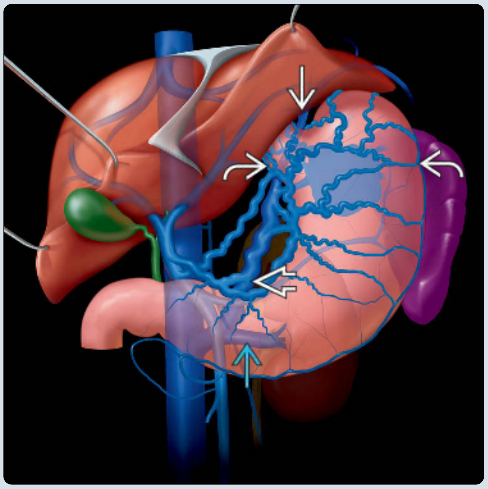
POST PROCEDURE

- Follow-up to evaluate for new/enlarged esophageal varices

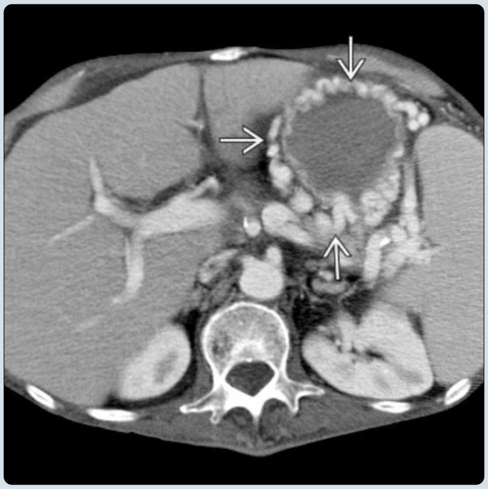
OUTCOMES

- Technical success: > 80-96%
- Active bleed control rate: 91-100%
- Improvement of hepatic encephalopathy (87-100%)
- Inadequate volume of sclerosant injected to opacify/visualize entire varices is cause for failure

(Left) *Graphic shows anatomy favoring balloon-occluded retrograde transvenous obliteration (BRTO). There are isolated gastric varices (GV) ↪ entering a large draining vein ⇨ that joins the left renal vein → [i.e., gastrorenal shunt (GRS)]. The left inferior phrenic vein → will require coil embolization.* **(Right)** *Axial CECT shows large GV →. Isolated GV are typically located in the cardia and are often poorly managed by endoscopy. If these varices drain into the left renal vein or inferior vena cava (IVC), they may be treated by BRTO.*

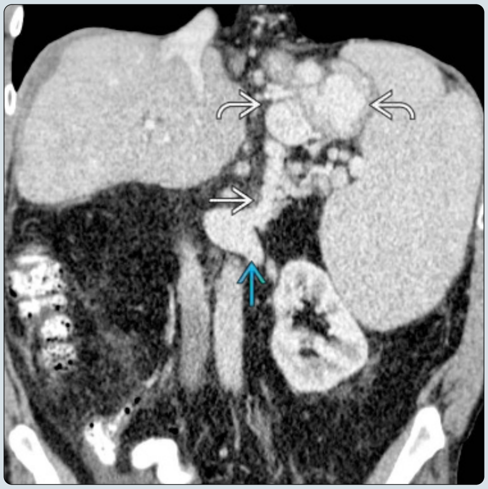


BRTO-Associated Anatomy

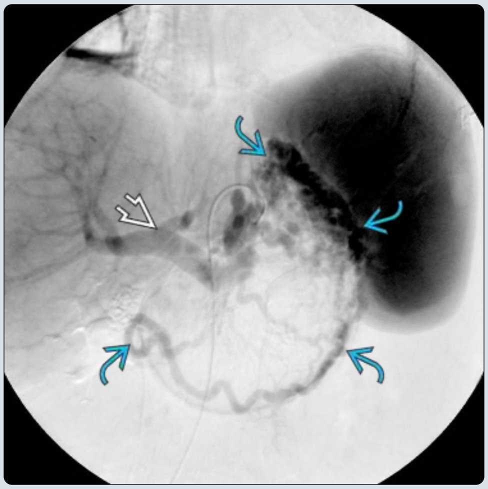


Gastric Varices

(Left) *Coronal CECT shows large GV ↪ and a large draining vein → communicating with the left renal vein →, providing potential access for BRTO.* **(Right)** *Delayed venous phase from a splenic arteriogram shows large GV ↪ and a patent portal vein ⇨. However, there is no filling of the splenic vein (concerning for splenic vein occlusion) and no evidence of a spontaneous shunt to the renal vein or IVC. Without portal hypertension, BRTO may not be appropriate.*



Gastrorenal Shunt



Splenic Vein Occlusion

TERMINOLOGY

Definitions

- **Balloon-occluded retrograde transvenous obliteration (BRTO)**: Method for treating gastric varices, which are associated with large spontaneous portosystemic venous shunt
  - Developed in Japan as transjugular intrahepatic portosystemic shunt (TIPS) adjunct/alternative; well established in Asia, slow acceptance in USA
  - Technique: Injection of sclerosant via balloon catheter positioned at outlet of vein draining gastric varices
    - Shunt is occluded with balloon, then sclerosant injected retrograde into varices
    - Causes thrombosis/obliteration of varices and obliterates gastrorenal shunt (GRS) or gastrocaval shunt (GCS)
  - Sclerosants
    - Ethanolamine oleate (EO): Sclerosant most reported with BRTO in literature; common in Asia, not popular in USA [sclerosant-induced renal failure antidote (haptoglobin) unavailable]; limited to 40 mL volume
    - Sodium tetradecyl sulfate (STS): Detergent sclerosant used in USA; mixed with air, allowing it to travel to distant and nondependent varices
    - Gelfoam: Gaining popularity, less risk of adverse event vs. EO; interventional radiologists more comfortable with its use vs. STS
  - BRTO variants
    - Plug-assisted retrograde transvenous obliteration (PARTO); placing Amplatzer plug in efferent shunt prior to delivery of sclerosant
    - Coil-assisted retrograde transvenous obliteration (CARTO); placing coil in dominant shunt prior to delivery of sclerosant
    - Balloon-occluded antegrade transvenous obliteration (BATO); accessing gastric varices via percutaneous transhepatic or TIPS approach, often considered bail-out for failed BRTO
  - BRTO vs. TIPS
    - BRTO: Flow redirected to liver, potentially improving hepatic encephalopathy and preserving liver function (6-9 months) but aggravating portal hypertension and potentially worsening esophageal varices (EV)
    - TIPS: Flow directed away from liver can result in worsening of encephalopathy and liver failure, especially if model for end-stage liver disease (MELD) > 19
    - Recurrent bleeding: Few studies comparing BRTO vs. TIPS with covered stent
      - Rebleed rate of patients post BRTO is 3-9% from gastric varices, but as high as 19-31% from all gastrointestinal sources
      - Rebleed rate for patients post TIPS is 11-22% when placed to treat EV, but as high as 13-53% from gastric varices
- **EV**
  - Venous saccules in esophageal wall, typically associated with portal hypertension, prone to rupture
  - Gastroesophageal varices
    - Located in lower esophagus and gastric cardia; drain into ascending EV
    - Usually treated endoscopically or with TIPS
- **GV**
  - Typically associated with portal hypertension and spontaneous portosystemic shunt (SPS)
  - Can be associated with occluded mesosplenoportal veins without portal hypertension
  - Incidence of bleed from GV
    - 25% overall
    - Fundal varices
      - 1 year: 16%
      - 3 years: 36%
      - 5 years: 44%
    - GV vs. EV
      - Bleed is more common from EV (75%) than GV (25%), and endoscopic management is more effective for EV vs. GV
      - Mortality higher with GV (45-55%) vs. EV; rationale for treatment of nonbleeding/at-risk GV patients
  - Isolated GV
    - May bleed despite portal gradient < 12 mm Hg
    - Located in fundus &/or cardia
    - Majority of fundal GV drain into left inferior phrenic vein
    - Endoscopy therapy poor; large, high-flow varices
    - Good indication for BRTO
- **SPS**
  - Often due to high portal pressure; rarely due to obstruction of portal venous system
  - Dictates approach for treatment of GV; understand afferent and efferent vein anatomy of SPS
  - Left-sided SPS
    - **GRS**: In 80-85% of GV cases
      - May be associated with large pericardiophrenic vein and GCS
      - Access point for BRTO
    - **GCS**: In 10-15% of GV cases
      - Left inferior phrenic/afferent gastric veins drain directly into inferior vena cava (IVC); may drain into left hepatic vein
      - Majority associated with collateral drainage: Left pericardial, thoracic wall, intercostal veins, anastomosis to right inferior phrenic vein
      - BRTO more difficult than in GRS
      - Least common of left-sided SPS
    - **Splenorenal shunt**: Not present with GV
  - Afferent veins of SPS (portal venous inflow)
    - **Left gastric vein (LGV)**: a.k.a. coronary vein
    - **Short gastric veins (SGVs)**: Often multiple, can have dominant vein
    - **Posterior gastric vein (PGV)**: Often single, can bifurcate
  - Efferent veins of SPS (systemic venous outflow)
    - **GRS**: Access point for BRTO
    - **Inferior phrenic vein (IPV)**: May require embolization prior to BRTO
    - Retroperitoneal veins: Small and variable
- **Gastric variceal complex (GVC)**
  - Combined GV and GRS
  - Multiple classification systems exist
  - Efferent (systemic based) classification

  - Practical information to plan treatment
  - Type A: Varices contiguous with single draining portosystemic shunt (no collateral flow)
    - Treatment: Standard BRTO technique
  - Type B: Varices contiguous with single shunt, plus 1 or more collateral veins
    - 3 subtypes exist: When high-flow collateral veins present, requires modification of standard technique
    - Treatment: Embolize collateral veins or advance occlusion catheter beyond collaterals
  - Type C: Varices contiguous with both GRS and GCS
    - Smaller shunt: embolize one with coils
    - Larger shunt: place occlusion balloons into outflow of both shunts
  - Type D: No GRS/GCS; varices drain via small collaterals not contiguous with either IVC or renal vein
    - Treatment: No BRTO; cannot be catheterized
- Afferent (portal based) classification
  - Often unknown prior to procedure; may explain failures but not alter treatment plan
  - Type 1: Supplied by single afferent gastric vein
    - Sclerosant fills entire varix, no spill out
  - Type 2: Supplied by multiple afferent gastric veins
    - Sclerosant can fill entire varix or spill into portal system
  - Type 3: Coexistent gastric branch veins directly contiguous with afferent feeder, not contributing to GV
    - Sclerosant can easily pass into portal system

PREPROCEDURE

Indications

- Isolated gastric varices at high risk for rupture (e.g., large varices, rapidly growing, red spots)
- Gastric varices that have already ruptured
- Treatment of portosystemic/hepatic encephalopathy refractory to medical management
- Ectopic varices (e.g., duodenal varices)
- When TIPS is not tolerated

Contraindications

- Portal vein occlusion
- Refractory ascites
  - Portal venous pressures will increase after BRTO
    - Obliterates large portosystemic shunt
- High-risk esophageal varices
  - Worsen after BRTO
  - Treat esophageal varices endoscopically prior to treatment with BRTO

Preprocedure Imaging

- Computed tomography angiography (CTA)/magnetic resonance angiography (MRA)
  - Coronal imaging often best
  - Delineate anatomy of varices and shunt
  - Determine diameter of gastrorenal shunt
  - Plan approach and optimal angle to cannulate shunt

Getting Started

- Things to check
  - Detailed clinical history
  - Allergies
  - Current medications
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Normal creatinine and GFR > 60
    - Coagulation status
      - Platelet count should be > 50,000/μL; platelet transfusion to maintain > 50,000 mL
      - Coagulants: May be abnormal due to liver disease
      - International normalized ratio (INR) recommended; fresh frozen plasma (FFP) to keep INR < 2.0
      - Activated partial thromboplastin time (aPTT) recommended; trend toward correcting aPTT values > 1.5x control
    - Blood bank sample
      - Possible ongoing transfusion requirements
    - Procedure/sedation/anesthesia consent
- Medications
  - Sclerosants
    - 3% STS [Sotradecol (AngioDynamics)]
      - Inexpensive
      - Detergent: Disrupts vein cellular membrane via protein theft denaturation
      - Foam mixture: Lipiodol:STS:air (or CO_2) in 1:2:3 ratio
      - Foam results in favorable sclerosant dose to volume ratio
    - 5% EO iopamidol
      - Mixture of 1:1 of 10% EO (Oldamin) and contrast (iopamidol 300mg/mL)
      - Induces hemolysis and releases free hemoglobin, which can cause renal tubular injury/renal failure
      - Administration of 4,000 U of haptoglobin recommended; binds with free hemoglobin
    - Sodium morrhuate [Scleromate; Glenwood)]
  - N-butyl-2-cyanoacrylate glue: Typically too expensive as sclerosant; can be used to embolize collaterals
  - Gelfoam: Inexpensive, readily available
- Equipment list
  - Large-diameter occlusion balloon (> 15 mm); large enough balloon to occlude shunt
    - Wide inner lumen through which microcatheter can be inserted [e.g., Berenstein large lumen occlusion balloon catheter (Boston Scientific)]
    - Reverse-shaped balloon catheters available in Asia
  - Vascular sheath (8- to 10-Fr)
  - Selective catheters (e.g., Cobra, Simmons, Kumpe)
  - Microcatheter and wire
  - Wires (e.g., Glidewire, Bentson, Amplatz, Rosen)
  - Embolization materials: Coils, Amplatzer, glue

PROCEDURE

Procedure Steps

- Review all appropriate imaging (coronal view)
- Obtain venous access: Right femoral or internal jugular vein, approach giving best angle to cannulate GRS
- **Obtain diagnostic venogram of shunt**
  - Advance vascular sheath to IVC; length and diameter of sheath based on preprocedure image review

  - Catheterize left renal vein using angled catheter (e.g., Cobra) and 0.035" wire (e.g., Glidewire or Rosen)
  - Advance sheath into proximal left renal vein
  - Catheterize GRS with "pull back venogram"
    - Rotate Cobra catheter superiorly and pull back, catheter falls into shunt, inject contrast to confirm location; alternatively, exchange for angle-tipped catheter to select shunt
    - Or, advance 10-Fr TIPS sheath over 0.035" guidewire into left renal vein, remove sheath inner dilator, pull back sheath over 0.035" wire until sheath falls into shunt, inject contrast to confirm
  - Advance Glidewire into shunt, advance 5-Fr catheter, inject contrast to confirm location and shunt diameter
  - Exchange Glidewire for stiff guidewire, remove catheter
  - Advance vascular sheath (over inner dilator) into shunt
  - Advance large occlusion balloon into shunt
  - Perform balloon-occlusion digitally subtracted venography (DSV)
    - Define anatomy, classify type of varix
    - Identify any collateral drainage
    - Measure volume required to fill varix
- **Address collateral veins prior to variceal sclerosis**: Not all collaterals will require embolization; understand collateral flow characteristics and risk of nontarget sclerosant
  - Slightly decrease planned volume of sclerosant, preventing filling/spill-over through simple afferent collateral
  - Embolize necessary collaterals: Typically efferents (e.g., inferior phrenic, pericardiophrenic, retroperitoneal) or duplicated gastrorenal shunt; possibly afferents (e.g., short gastric, posterior gastric, left gastric)
    - Selectively catheterize collaterals
      - Retrograde approach: Advance 5-Fr or microcatheter through sheath into collateral vein; if collateral cannot be reach via retrograde approach, consider antegrade approach
      - Antegrade approach: Access collateral/shunt from portal venous side via percutaneous transhepatic/transileocolic or TIPS access
    - Embolize with coils, Gelfoam, Amplatzer, or glue depending on size and characteristics of collaterals
      - Staged, small-volume delivery of sclerosant into collaterals is also option
    - Repeat balloon-occlusion DSV after collateral embolization to confirm no residual collaterals; flow dynamics will change, new collaterals may become apparent
  - Bypass collaterals: Advance balloon occlusion catheter past collaterals, further into shunt, and plan to deliver sclerosant from this location
  - Balloon-occluded collaterals: Drainage vein may be large enough to catheterize retrograde with 2nd balloon catheter
  - If > 1 shunt present: May require 2nd occlusion balloon from 2nd venous access point (jugular, femoral)
  - Catheterization of collaterals may not be possible secondary to tortuosity or small size
    - Consider injecting slow nonselective Gelfoam pledgets; may decrease flow into collaterals, further opacify varix
  - If large collaterals result in poor opacification of varices with single balloon, consider double-balloon technique
    - Place large balloon catheter at outlet of shunt
    - Coaxially advance 2nd smaller balloon through larger balloon catheter, past collateral drainage
    - Insert microcatheter coaxially through smaller balloon, into varices for opacification and embolization/sclerosis
- **Inject sclerosant with occlusion balloon inflated**
  - Sclerosant volume often 30-40 mL, can exceed 50 mL
  - Use coaxial microcatheter for more selective injection
    - Minimizes volume of sclerosant
    - Minimizes risk of balloon rupture
  - Inject slowly until GV completely filled
    - Radiodense sclerosant (e.g., STS foam with lipiodol) is observed as it fills varix
    - Or, varix can be filled with dilute contrast, then observed while radiolucent sclerosant (e.g., STS foam without lipiodol) is injected, displacing contrast
    - Minimal afferent vein &/or portal vasculature filling is optimal
  - Consider digital subtraction angiography (1-2 frames/second) during sclerosant injection; watch for overflow/spill into portal system
    - Some collaterals not initially apparent may present during sclerosis
  - Inadequate sclerosant volume to fill entire variceal complex is cause for failure
    - Underestimating total volume of variceal complex may occur during diagnostic venogram
    - Sclerosant may leak through patent collaterals, preventing successful treatment of varices
  - Balloon remains inflated throughout period of active sclerosis
    - Sclerosant dwell times of 4-24 hours suggested
  - Duration of active sclerosis based on sclerosant/embolic used and protocol employed
  - Transfer patient to intensive care unit (ICU); overnight balloon inflation may be necessary
    - Lengthy bedrest and risk of malpositioned catheter
- **Procedural completion**
  - Return to fluoroscopy suite; prep and drape patient
  - Aspirate as much sclerosant as possible
    - Serious complications can arise from sclerosant extending into portal or systemic vasculature
  - Deflate balloon catheter and remove
  - Perform venogram of left renal vein; ensure patency without thrombus
- **BRTO alternate: (Vascular) PARTO**
  - Obtain diagnostic venogram of shunt
  - Define and address collateral veins
  - Advance guide catheter (6- to 8-Fr) into GRS
  - Perform venogram of shunt, determine narrowest part
  - Advance on 0.035" guidewire through guide sheath into gastric varix
  - Deploy Amplatzer Vascular Plug II (AGA Medical) (10-22 mm) into shunt where most narrow
    - Oversize Amplatzer appropriately (typically 15-30%)
    - Do not release Amplatzer
  - Advance 4-Fr catheter over guidewire into gastric varix
  - Wait 5-10 minutes for occlusion of shunt

  - Perform slow retrograde venography via 4-Fr catheter
    - Confirm occlusion of efferent shunt by Amplatzer; if not, consider repositioning Amplatzer or adding Gelfoam slurry to shunt
    - Look for additional collaterals; embolize with Gelfoam/coils via 4-Fr or coaxial microcatheter
  - Determine volume of gastrorenal variceal complex
  - Deliver Gelfoam slurry through 4-Fr catheter into gastrorenal variceal complex
  - Remove catheter
  - Detach Amplatzer
  - Perform left renal venogram via guide catheter

Alternative Procedures/Therapies

- Other
  - In absence of portal hypertension
    - Focal splenic/portal occlusion may be recanalized and stented via endovascular means or surgically repaired
    - Focal varices may be surgically resected along with involved bowel and mesentery

POST PROCEDURE

Things to Do

- Follow-up CTA, MRA, or endoscopic US to confirm obliteration of varices in ~ 2 weeks
  - Can predict long-term efficacy of BRTO
- Periodic endoscopy to evaluate for recurrence or new varices; band ligate new esophageal varices
- Partial obliteration can undergo repeat BRTO
  - Regrowth or persistent varices at 3 months should undergo repeat treatment
  - May embolize spleen prior to repeat treatment
    - Decreases flow in shunt
    - Repeat BRTO 2 weeks after splenic embolization

OUTCOMES

Complications

- Most feared complication(s)
  - Major complications: 3% (portal/splenic and IVC/iliac venous thrombus, pulmonary emboli, sclerosant extravasation, other)
- Immediate/periprocedural complication(s)
  - Sclerosant EO may induce renal failure due to hemolytic effect
    - Hematuria expected with EO sclerosant
  - Systemic venous thrombosis (as high as 15%)
  - Low-grade fevers (51%) and abdominal and back pain common; treat conservatively
- Delayed complication(s)
  - Increased portal pressures
    - Worsening of existing EV
      - ☐ Year 1 (27-35%)
      - ☐ Year 2 (45-66%)
      - ☐ Year 3 (45-91%)
    - New EV in patient who had none (> 50%)
    - Hepatic hydrothorax and ascites (9-33%)

Expected Outcomes

- BRTO
  - Technical success: > 80-96%
  - Clinical success: 97% (no gastric variceal recurrence/rebleed; complete obliteration on subsequent imaging)
  - Active bleed control rate: 91-100%
  - Rebleed rate: GV (3-9%) vs. all GI sources (19-31%)
  - Patient survival
    - Year 1 (83-98%)
    - Year 3 (66-100%)
    - Year 5 (39-85%)
  - Improvement of hepatic encephalopathy (87-100%)
    - Increased hepatopetal flow and decreased plasma ammonia
    - Long-term efficacy not yet confirmed
  - Improved hepatic synthetic function for 6-9 months, then return to baseline
- PARTO
  - Similar results as for BRTO
  - Combined with Gelfoam slurry: 95% technical success, 26% aggravated EV, 11% rebleed rate
- BATO
  - Technical success: > 90-100%

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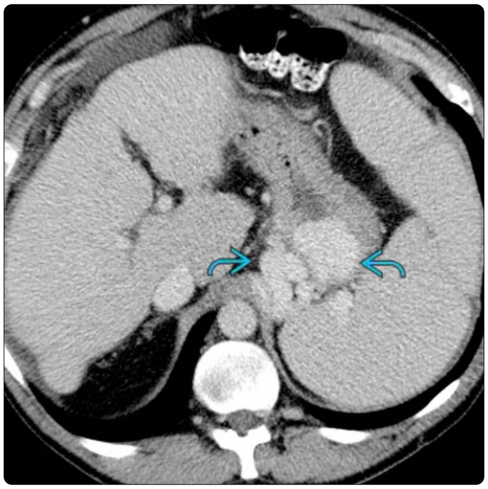
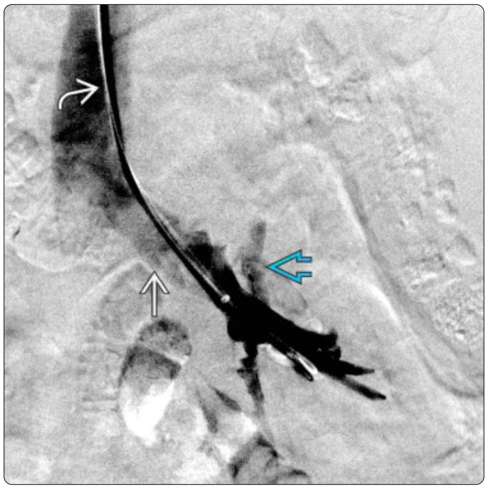
Step-by-Step: BRTO Technique (Preprocedure Imaging)

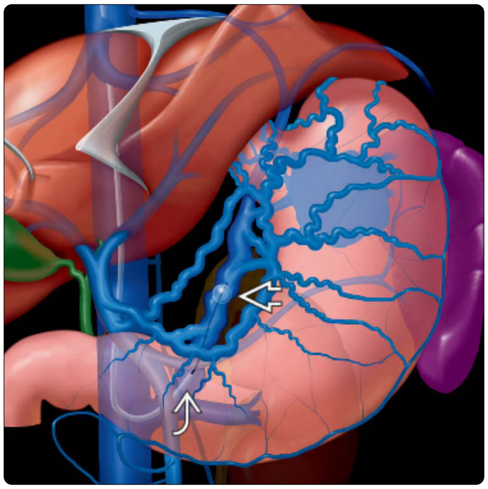


Step-by-Step: BRTO Technique (Left Renal Venography)

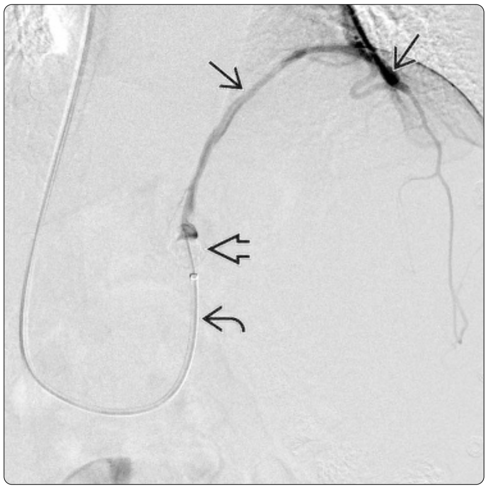


(Left) *Axial CECT obtained in a patient with upper gastrointestinal (GI) bleeding shows extremely large GV* ↪ *in the gastric cardia with sparing of the remainder of the stomach. Endoscopy excluded any esophageal varices (i.e., isolated GV). Splenomegaly suggests portal hypertension. BRTO was indicated.* **(Right)** *A curved sheath* ↪ *introduced from a jugular approach was advanced into the left renal vein* →*. Digital subtraction venography (DSV) shows trace filling of the GRS* ⇨*.*

Step-by-Step: BRTO Technique (Occlusion Balloon Venogram)

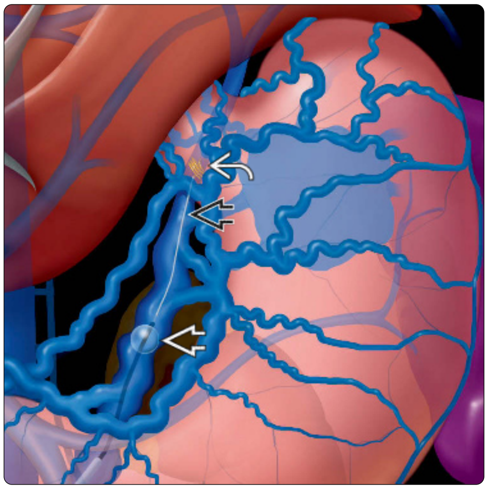


Step-by-Step: BRTO Technique (DSV of Gastric Varices and Portosystemic Shunt)

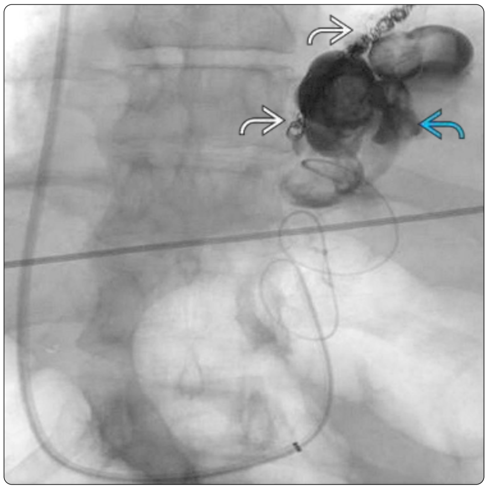


(Left) *The guiding sheath* ↪ *is advanced into the GRS. A balloon occlusion catheter* ⇨ *has been coaxially introduced via the sheath and inflated in the shunt.* **(Right)** *DSV shows curved sheath* ↪ *advanced into the GRS and the coaxial occlusion balloon catheter* ⇨ *introduced and inflated. Contrast injection reveals a large left inferior phrenic vein* → *(efferent portosystemic shunt) that will require embolization prior to gastric variceal sclerosis.*

Step-by-Step: BRTO Technique (Embolization of Efferent Shunts)



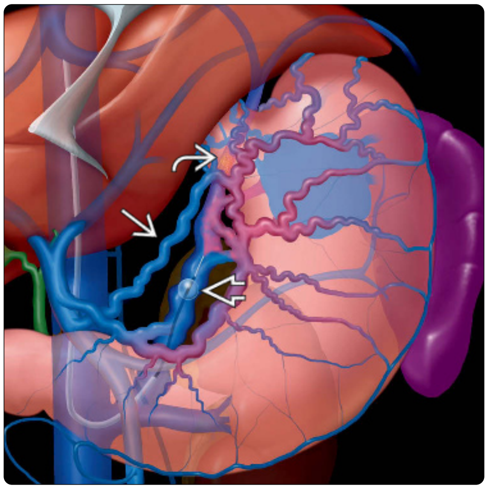
Step-by-Step: BRTO Technique (Calculate Volume of Sclerosant)



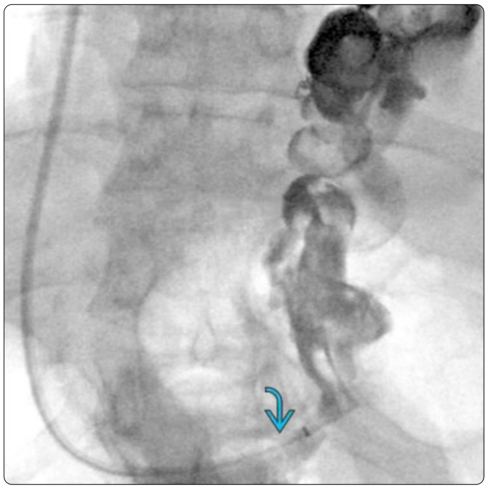
(Left) *A microcatheter* → *has been introduced through the occlusion balloon catheter* ⇨ *and into the left inferior phrenic vein where embolization coils* ↪ *are being placed.* **(Right)** *After successful coil embolization of the left inferior phrenic vein* ↪*, contrast is injected into the GV* ↪ *to search for additional draining veins (it is important that collateral pathways are occluded to prevent sclerosant egress into nontarget areas) and to determine the volume of sclerosant needed to entirely fill the varices.*

(Left) *Graphic shows that the sclerosant has been injected into the varices (signified by purple), while the occlusion balloon ➡ remains inflated. The coils ➡ block the (efferent) inferior phrenic vein. Care must be taken during injection so as not to spill sclerosant out of the patent (afferent) left ➡ or posterior/short gastric veins.* **(Right)** *The balloon was kept inflated overnight. The next day, sclerosant was aspirated, the balloon was deflated, and then contrast gently injected via the guiding sheath ⇨. No flow remains.*

Step-by-Step: BRTO Technique (Sclerosant Injection)

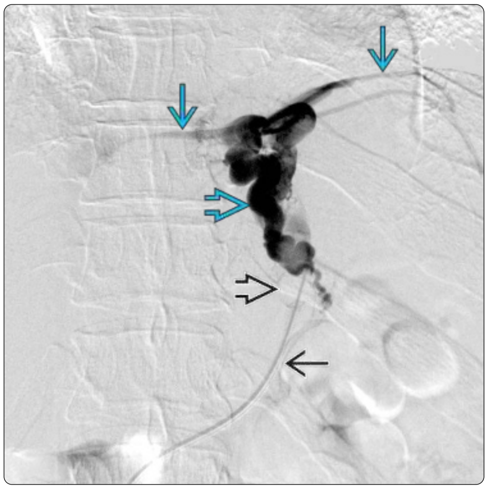


Step-by-Step: BRTO Technique (Post-Sclerosant Dwell)

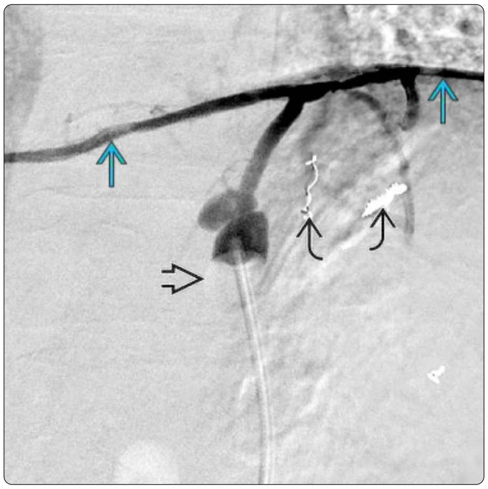


(Left) *Simmons catheter and 0.035" wire were pulled back within the left renal vein to engage the GRS, and a guiding sheath ⇨ subsequently advanced. DSA venography through an inflated occlusion balloon catheter ⇨ opacifies the GV ⇨ as well as the left inferior phrenic collateral veins ⇨.* **(Right)** *The balloon was advanced through the shunt into the GV, where it was reinflated ⇨. Contrast injection better defines the inferior phrenic vein ⇨ for microcatheter coil embolization ↪.*

Transfemoral BRTO (Occlusion Balloon Retrograde Venogram)

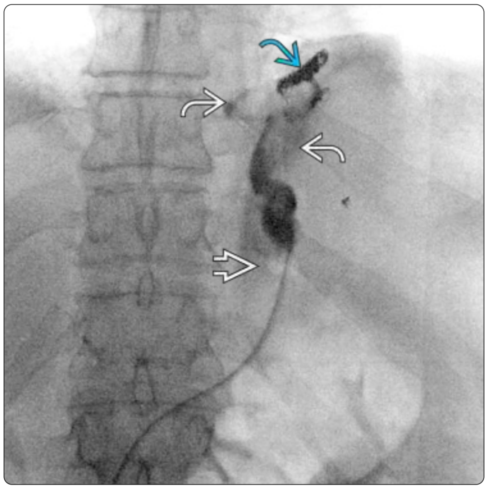


Transfemoral BRTO (Coil Embolization)

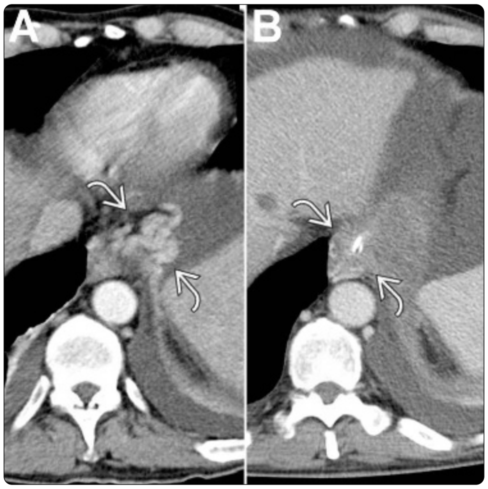


(Left) *After coil embolization of the left inferior phrenic vein ↪, sclerosant injection, elapsed dwell time, and sclerosant aspiration, the balloon ➡ was deflated. Contrast injected via the balloon catheter shows intraluminal filling defects ↪ and no contrast flow into the GV, indicating successful sclerosis.* **(Right)** *CECT images (A) before and (B) 2 weeks after BRTO show that the fundal GV ↪ significantly decreased in size.*

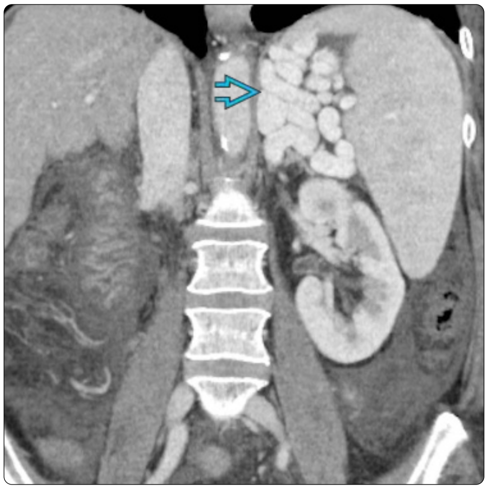
Transfemoral BRTO (Completion Venography)



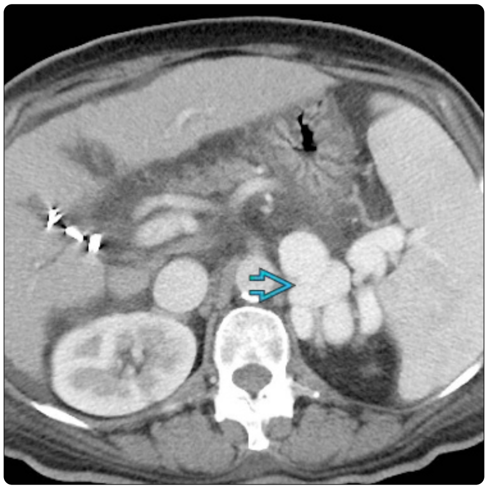
Transfemoral BRTO (Pre/Postprocedure)



Vascular Plug-Assisted BRTO (Coronal CECT)

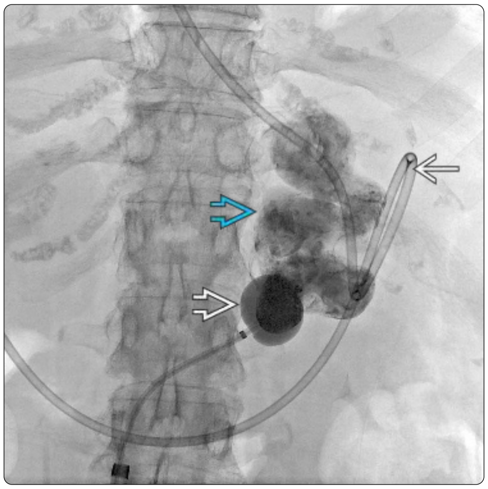


Vascular Plug-Assisted BRTO (Axial CECT)

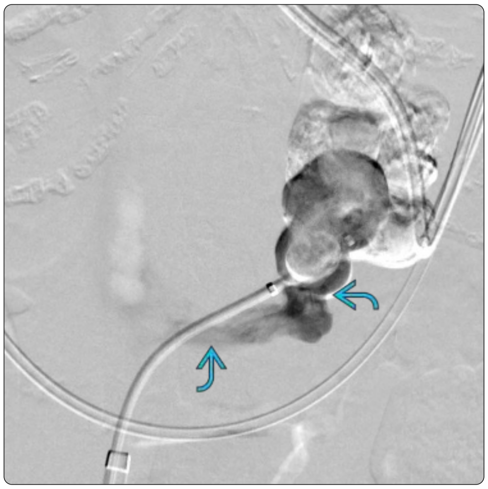


(Left) Coronal CECT shows enlarged GV ➩ associated with the portosystemic shunt in this patient with portal hypertension. **(Right)** *The GV ➩ are well seen on CECT. Splenomegaly is present, suggesting portal hypertension.*

Vascular Plug-Assisted BRTO (Injection of Sclerosant)

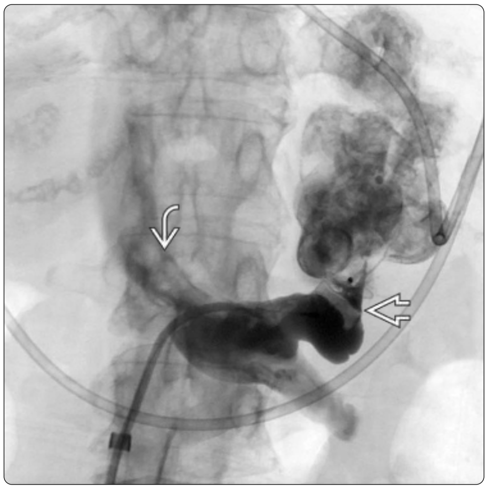


Vascular Plug-Assisted BRTO (Balloon Deflation After Dwell Time)

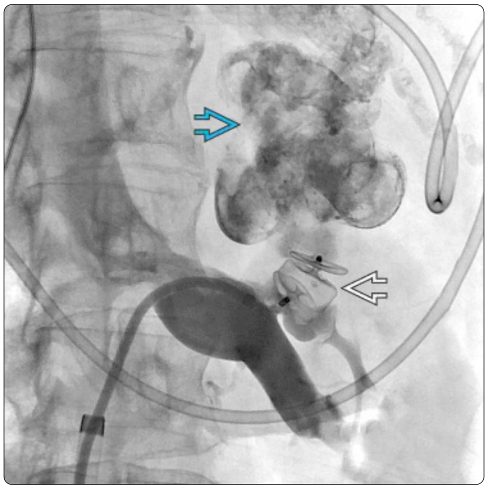


(Left) *With a balloon catheter ➡ inflated within the GRS, 40 cc of sodium tetradecyl sulfate (STS) sclerosant foam was injected into the GV ➩ via the balloon catheter lumen. Incidentally noted is a nasojejunal feeding tube seen passing through the gastric lumen ➡.* **(Right)** *Eighteen hours later, aspiration of any remaining sclerosant was performed and the balloon catheter deflated. Contrast was then injected through the balloon catheter into the GRS. Patent flow ↪ remained within the shunt.*

Vascular Plug-Assisted BRTO (Deployment of Amplatzer)

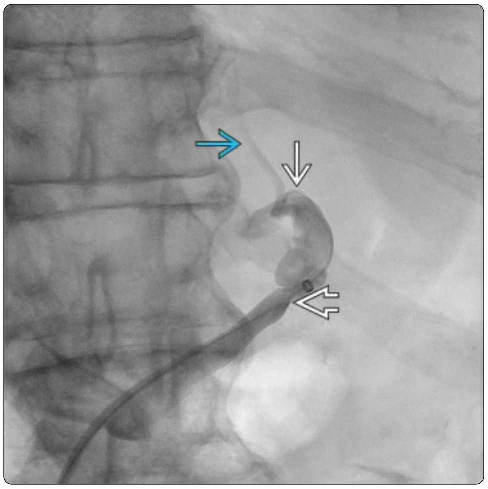


Vascular Plug-Assisted BRTO (Final Left Renal Venogram)

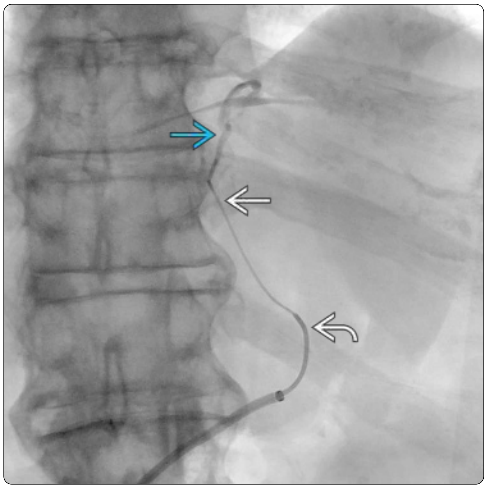


(Left) *The balloon catheter was exchanged for a guidecatheter through which an Amplatzer Vascular Plug ➡ was advanced. The plug would not advance into the superior (often tortuous) intraperitoneal portion of the GRS but stayed within the inferior (often linear) retroperitoneal portion. Note the venous thrombus ➡.* **(Right)** *Final renal venography shows the Amplatzer ➡ well positioned and the renal vein patent. Vitals remained unchanged. GV ➩ were entirely occluded on follow-up CT.*

(Left) *In another patient, a guide sheath ⇨ was advanced into the GRS, and venography performed via a microcatheter → advanced into GV. A patent left inferior phrenic vein → is seen.* **(Right)** *A 4-Fr catheter ↪ was advanced into the GV, and the microcatheter → coaxially advanced into the left gastric vein → for subsequent coil embolization.*

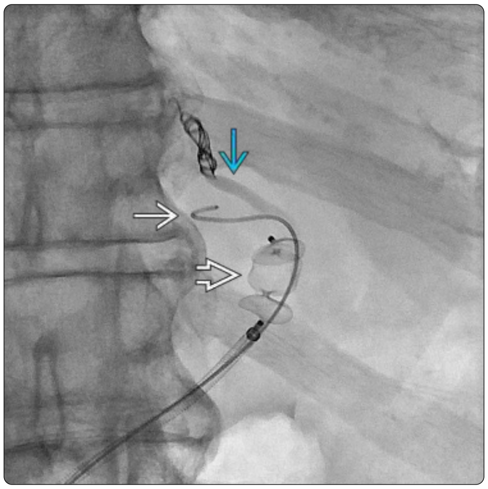


Step-by-Step: PARTO (Access and Venography)

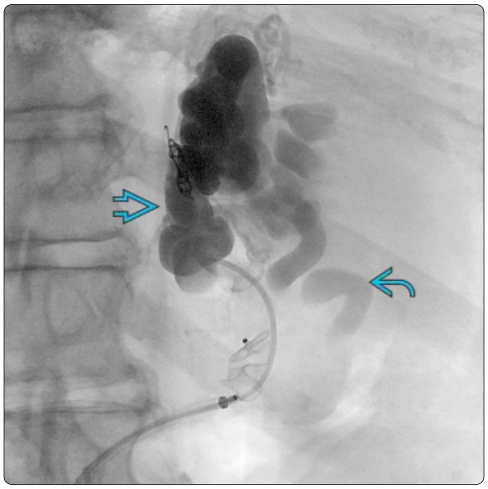


Step-by-Step: PARTO (Embolization of Left Inferior Phrenic Vein)

(Left) *Once embolization of potential nontarget efferent veins → is assured, an 0.035" wire → (optional: With 4-Fr catheter) is placed into the GV. An Amplatzer ⇨ is then advanced through the same guide sheath and deployed (not released) within the narrowest portion of the GRS.* **(Right)** *Contrast is injected into the GV ⇨ to determine the volume of sclerosant necessary and to look for additional collateral veins requiring embolization. In this case, a (afferent) posterior gastric vein ↪ is seen.*

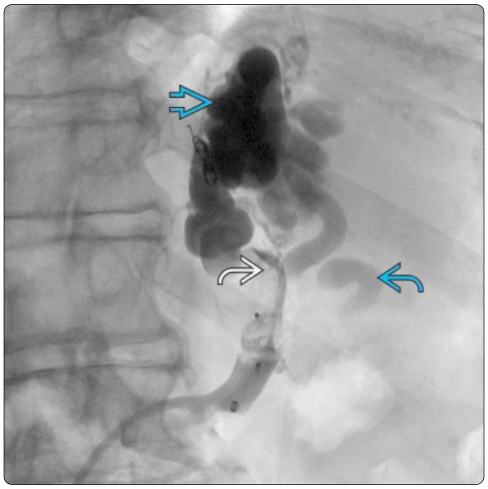


Step-by-Step: PARTO (Vascular Plug Placement)

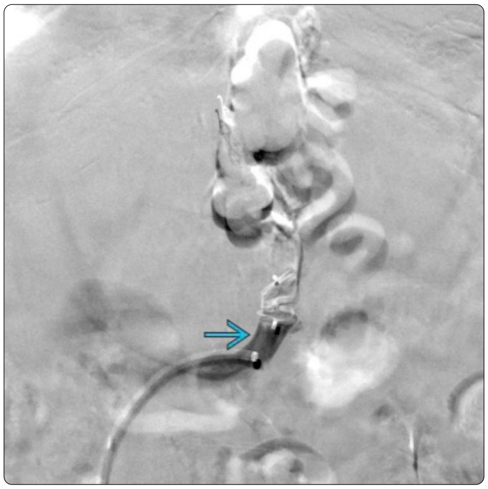


Step-by-Step: PARTO (Determination of Sclerosant Volume)

(Left) *Embolization of the afferent vein ↪ was attempted but unsuccessful. Ultimately, sclerosant was delivered through the 4-Fr catheter ↪ into the GV ⇨, halting delivery once filling of the afferent vein occurred (to prevent spillover into the portal vein). The Amplatzer was then released.* **(Right)** *Final venography from the GRS → confirms stasis of flow. PARTO removes the need for the patient to return for a repeat procedure (balloon removal) following the sclerosant dwell time.*

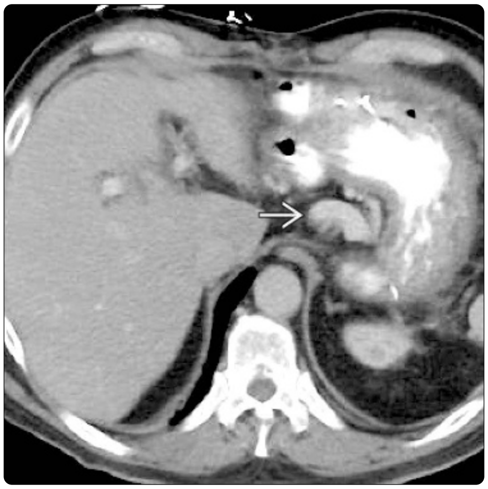


Step-by-Step: PARTO (Delivery of Sclerosant)

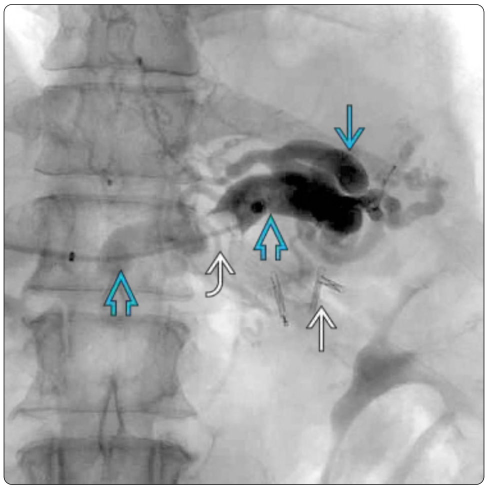


Step-by-Step: PARTO (Final Venogram)

Spontaneous Mesoportal Shunt (Gastric Varices)

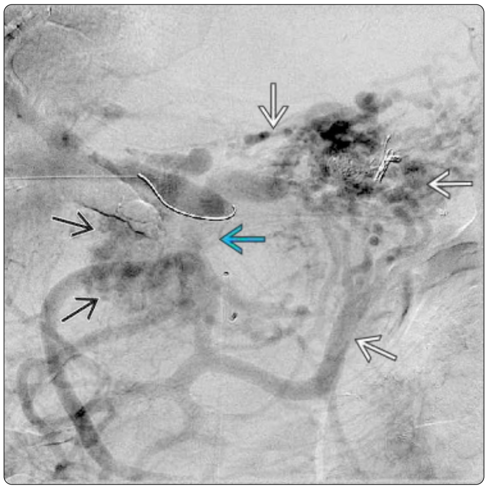


Spontaneous Mesoportal Shunt (Gastric Variceal Shuntogram)

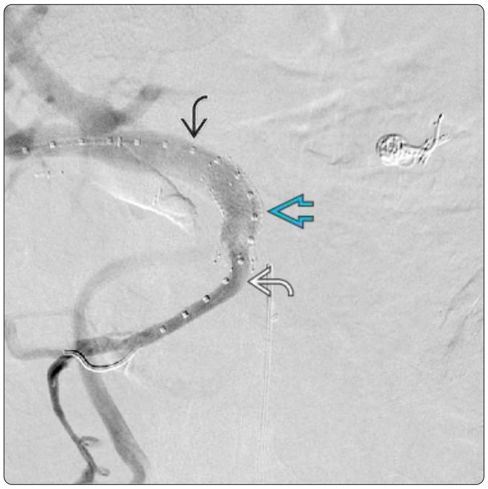


(Left) *A 60-year-old man with remote pancreatitis presented with intermittent GI bleeding for over 1 year. CECT revealed GV* ➡ *but no GRS. EGD excluded esophageal varices.* **(Right)** *EGD clips* ➡ *halted the active bleeding; BRTO was requested to prevent future bleeding. Percutaneous transhepatic portal venous access was achieved for planned BATO. Balloon-occluded* ➡ *venography revealed dilated left gastric vein* ⇨ *and GV* ⇨ *and hepatopetal flow (toward liver). Portal hypertension was excluded.*

Spontaneous Mesoportal Shunt (Superior Mesenteric Arteriogram, Venous Phase)

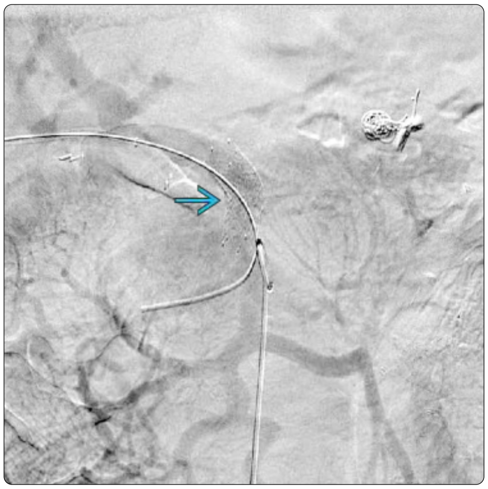


Spontaneous Mesoportal Shunt (SMV Recanalization and Stenting)

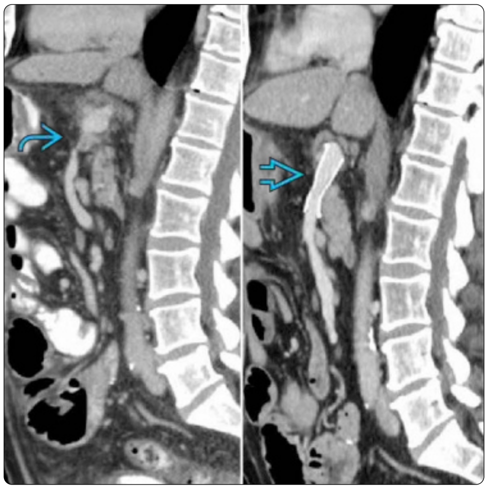


(Left) *Superior mesenteric arteriogram reveals portal venous flow. Occlusion of the superior mesenteric vein* ⇨ *(not mentioned on CECT) resulted in right-* ⇨ *and left-* ➡ *sided mesoportal shunting.* **(Right)** *Embolization of the mesoportal shunt could have resulted in bowel ischemia. Instead, variceal blood flow was reduced by restoring in-line superior mesenteric vein (SMV)* ➡ *to portal* ⇨ *flow across the SMV occlusion, recanalizing the occlusion* ⇨ *via the percutaneous transhepatic access.*

Spontaneous Mesoportal Shunt (Superior Mesenteric Arteriogram, Venous Phase)



Spontaneous Mesoportal Shunt (Pre and Post CT)



(Left) *Repeat superior mesenteric venous phase angiogram confirms patency of the SMV* ⇨ *with almost no residual flow seen within right and left mesocaval shunts. Reduced risk of bleeding was achieved without embolization or compromise of small bowel venous drainage.* **(Right)** *(L) Retrospective review shows SMV occlusion* ⇨ *prior to recanalization and stenting. (R) CECT obtained 3 years after stenting confirms patent SMV* ⇨*. The patient had no further episodes of variceal bleeding.*

Portal Vein Embolization

KEY FACTS

TERMINOLOGY

- **Portal vein embolization (PVE)**: Preoperative embolization of portal vein branches in order to induce hypertrophy of unembolized portion of liver
- **Future liver remnant (FLR)**: Anticipated volume of liver remaining after partial hepatectomy

PREPROCEDURE

- Patients who are otherwise candidates for surgical management of primary or metastatic hepatic tumors but would not have sufficient remaining liver after resection
  - Minimal volume of FLR required for resection
    - 20% in those with otherwise normal livers
    - 40% in those with cirrhosis

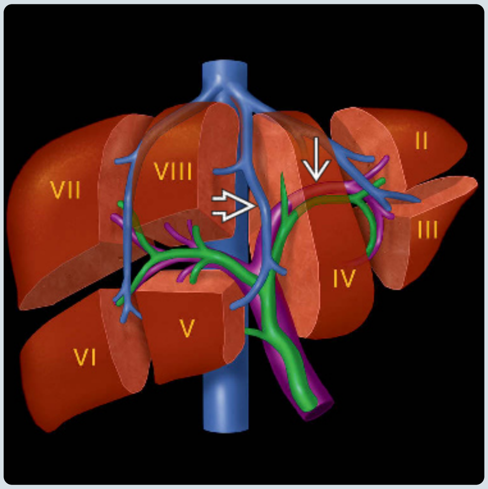
PROCEDURE

- Initial access: Percutaneous introduction of a 22-g Chiba needle into portal system
  - **Contralateral approach**: Access on side opposite of embolization target (usually left access)
  - **Ipsilateral approach**: Access on side of embolization target (usually right access)
  - **Transsplenic approach**: Access of portal system through spleen instead of liver
- Advance wire into main portal vein and place sheath
- Introduce selective catheters via sheath and perform selective portograms
  - Reverse-curve catheter (ipsilateral approach)
  - Forward-facing catheter (contralateral access)
- Deliver embolic agent until stasis is achieved
- Consider prophylactic tract embolization

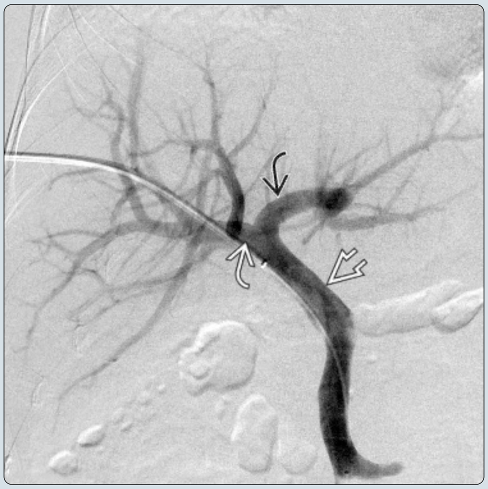
OUTCOMES

- FRL volume increases of 30-45% reported at 30 days
- Successful hepatic resection rates of up to 85-90% after PVE
- Major complications in 6%, minor complications in 11%

Couinaud Anatomy

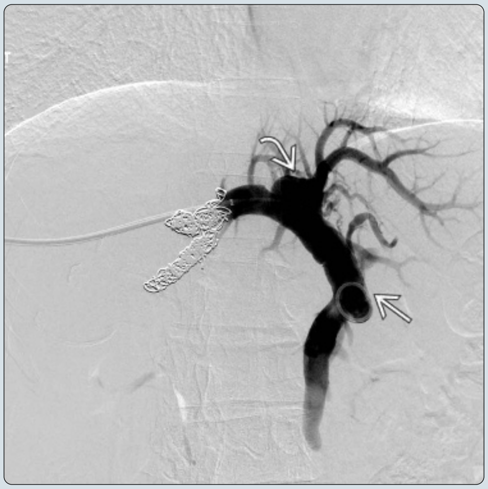


Portogram

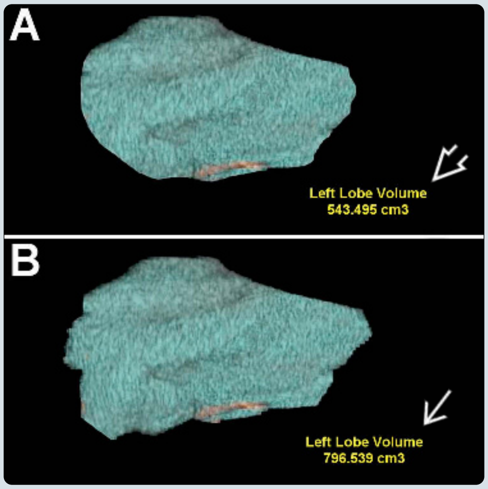


(Left) *Graphic demonstrates the Couinaud hepatic segmental anatomy, wherein each of 8 segments is centrally supplied by a portal vein →, hepatic artery, and bile duct branch and is drained by a hepatic vein ⇨.* **(Right)** *Portal venography demonstrates the main portal vein ⇨ dividing into right ↪ and left ↪ portal veins, which yield segmental branches. Understanding segmental anatomy is essential to good PVE outcomes.*

Portogram After Right PVE



CT Volumetric Evaluation of Future Remnant Liver



(Left) *Portogram after distal right portal vein embolization with a combination of particles and coils confirms adequate embolization as well as preserved patency of the main → and left ↪ portal veins.* **(Right)** *3D reformation of the left hepatic lobe (future remnant liver) (A) before and (B) 4 weeks after portal vein embolization shows the calculated preembolization FRL volume ⇨ of 543.495 cm^3 and the postembolization volume → of 796.539 cm^3. This is an ~ 32% volumetric increase in the future remnant liver.*

TERMINOLOGY

Definitions

- **Portal vein embolization (PVE)**: Preoperative embolization of portal vein branches used to induce hypertrophy of unembolized portion of liver
  - Usually used in cases of diseased right lobe requiring embolization to induce hypertrophy of left lobe
  - As right lobe is normally larger than left, it is usually of sufficient size for resection of left lobe without PVE
- **Future liver remnant (FLR)**: Anticipated volume of liver remaining after partial hepatectomy
- **Total estimated liver volume (TELV)**: -794.41 + 1267.28 x body surface area
- **Degree of hypertrophy (DH)**: Difference between ratio of FLR volume to TELV before and after PVE
- **Kinetic growth rate (KGR)**: Weekly FLR growth after PVE

PREPROCEDURE

Indications

- Patients who are otherwise candidates for surgical management of primary or metastatic hepatic tumors but would not have sufficient remaining liver after resection
  - Colorectal cancer is most common primary malignancy treated with hepatic resection
- Management of HCC following TACE in order to decrease tumor burden while awaiting surgical resection
- Complex hepatectomy as part of pancreatectomy
- PVE has also been performed prior to resection of sclerosing cholangitis
- Minimal volume of FLR required for resection
  - Normal liver function: 20%
  - Higher minimal volume of FLR required with impaired hepatic function
    - High-dose chemotherapy (> 12 weeks): 30%
    - Underlying cirrhosis: 40%
    - Other causes of impaired liver function include cholestasis, fibrosis, steatosis

Contraindications

- Contraindications closely resemble those for hepatic resection
- **Absolute contraindications**
  - Uncorrectable coagulopathy
  - Complete lobar portal vein thrombosis or occlusion
  - Extensive invasion of portal vein by tumor
  - Overt clinical portal hypertension
- **Relative contraindications**
  - Massive ascites: Perform paracentesis first
  - Biliary dilation within FLR: Perform biliary drainage first
    - Biliary drainage of FRL is necessary to promote hypertrophy

Getting Started

- Things to check
  - Surgical plan, including if segment IV will be resected
  - Allergies
  - Labs and medications, based upon "moderate risk of bleeding" per SIR consensus guidelines
    - Labs
      - ▫ Complete blood count: Platelet count > 50,000/μL
      - ▫ International normalized ratio (INR) ≤ 1.5
    - Medications
      - ▫ Ticlopidine: Withhold 7 days before procedure
      - ▫ Dabigatran & fondaparinux: Withhold 2-3 days before procedure (or 3-5 days if CrCl < 50 mL/min)
      - ▫ Clopidogrel: Withhold 5 days before procedure
      - ▫ Low molecular weight heparin (therapeutic): Withhold 12 hours before procedure
      - ▫ Aspirin: Do not withhold
  - Antibiotic prophylaxis
    - SIR guidelines: Routinely recommended, but no consensus on 1st-choice agent
    - Should cover *S. aureus*, *S. epidermidis*, *Streptococcus spp.*, *Corynebacterium spp.* &/or enteric flora
  - Informed consent: PVE-specific considerations
    - Hemorrhage or subcapsular hematoma
    - Hemobilia or bile leak
    - Nontarget embolization or thrombosis
    - Failure to induce adequate hypertrophy despite technical success
- Equipment list
  - Access needle/sheath
    - 22- to 18-g needle (e.g., Chiba or trocar)
    - Introducer sheath
    - Vascular sheath
  - Guidewires
    - 0.018" guidewire for initial access
    - 0.035-0.038" guidewire for catheter introduction
    - 0.035" hydrophilic guidewire as needed for branch selection
  - Selective catheters
    - 5-Fr forward-facing catheter (contralateral approach)
    - 5-Fr reverse-curve catheter (ipsilateral approach)
    - 3-Fr microcatheter (both approaches)
      - ▫ Optional
  - Desired embolic agents
    - Particles: Distal embolization
      - ▫ Polyvinyl alcohol (PVA)
      - ▫ Contour PVA particles (Boston Scientific): Spherical PVA particles
      - ▫ Bead Block (Terumo Medical): Calibrated hydrogel PVA microspheres
      - ▫ Embospheres (Merit Medical): Tris-acryl gelatin microspheres
      - ▫ Embozene (CeloNova BioSciences): Hydrogel core microspheres coated with Polyzene-F polymer
    - Liquids: Distal embolization
      - ▫ Ethanol: Toxic to endothelium, activates coagulation cascade, causes RBC microaggregation
      - ▫ N-butyl cyanoacrylate: Solidifies with ionic contact, causes intense inflammation and hypertrophy
      - ▫ Thrombin: Activates fibrinogen to assemble into fibrin; reports of recanalization using this agent
      - ▫ Fibrin glue: Separate fibrinogen and thrombin solutions that form fibrin clot when mixed; reports of recanalization using this agent
    - Mechanical: Proximal occlusion, usually combined with distally occluding agents
      - ▫ Coils: Various proprietary designs

        - Amplatzer vascular plug (St. Jude Medical): Expandable nitinol wire mesh

Preprocedural Imaging

- CT volumetry
    - Preoperative measurement of FLR is important in ensuring adequate functional liver postoperatively
    - 3D CT volumetry has become standard for measuring liver volume
        - Can use to measure total liver volume as well as lobar or segmental volumes as needed
    - Remember to exclude tumor volume when measuring FLR
- Can also review US, cross-sectional imaging for vascular anatomy and procedural approach planning

PROCEDURE

Patient Position/Location

- **Contralateral approach**: Access on side opposite of embolization target (usually left access)
    - Anterior subxiphoid area
    - Easier, antegrade catheterization of right branches
    - Must traverse FLR
        - Injury to FLR could jeopardize surgical candidacy
- **Ipsilateral approach**: Access on side of embolization target (usually right access)
    - Right midaxillary line
    - Avoids traversal of FLR
    - Theoretical risk of seeding if tumor is traversed
    - May be difficult to catheterize right portal vein branches due to sharp angulations (reverse curve catheter and microcatheter helpful)
- **Transsplenic approach**: Percutaneous access of portal system through spleen instead of liver
    - Left upper quadrant at level of splenic vein branch
    - May avoid risks associated with transhepatic access
        - Allows for contralateral access without FLR traversal
    - Equally as successful as transhepatic approach for PVE in those experienced with transsplenic access

Procedure Steps

- **Access approach for right PVE**
    - Contralateral: Target segment III left portal branch
        - Introduce Chiba needle in anterior subxiphoid area, directed slightly right
    - Ipsilateral: Target peripheral right portal branch
        - Introduce Chiba needle at mid-axillary line below last rib, or in most intercostal interspace, perpendicular to lateral abdominal wall, angling needle toward T12/L1
    - Percutaneous transsplenic access also described
- **Step-by-step portal venous access**
    - Sterilely prepare and drape skin overlying target
    - Administer 1% lidocaine at access site and along tract
    - Make small skin nick with #11 blade
    - If using US guidance (optional)
        - Portal vein has hyperechoic peripheral halo
        - Identify medium-caliber, somewhat peripheral portal vein branch
    - Advance 22-g Chiba needle into liver
        - Aspirate for blood: If no return, slowly withdraw needle under fluoroscopy while aspirating; upon blood return, inject contrast to opacify vein
            - Contrast in hepatic vein flows centrally to IVC
            - Contrast in portal vein flows peripherally (may flow toward main portal vein in cirrhotic)
        - Alternatively to aspiration, inject contrast while slowly withdrawing needle under fluoroscopy
            - This technique can obscure visualization as contrast builds up in hepatic parenchyma; inject contrast sparingly
    - If access not achieved while withdrawing needle, do not remove from hepatic capsule; maintain same trajectory toward vertebra but alter needle course by 5° anteriorly/posteriorly (right access) or 5° superiorly/inferiorly (left access) and re-advance Chiba needle with stylet
    - If needle in hepatic vein, opacify to determine if right, middle, or left hepatic vein
        - If right hepatic vein, portal vein is anterior
        - If middle hepatic vein, portal vein is posterior
        - If left hepatic vein, portal vein is inferomedial
    - Once needle in portal branch, advance 0.018" guidewire into main portal vein
    - Exchange for coaxial introducer and 0.035" guidewire
    - Place 5- to 6-Fr vascular sheath
        - Contralateral approach: Advance into main portal vein
        - Ipsilateral approach: Advance into right portal vein
    - Introduce pigtail catheter into main portal vein
        - Obtain DSA portogram (multiple projections)
- **Select portal branch for embolization**
    - In case of planned segment IV embolization
        - Perform segment IV embolization first if ipsilateral approach, last if contralateral approach
    - Engage desired brach for embolization
        - Advance 4- to 5-Fr catheter into target branch
        - Consider microcatheter to achieve distal access
    - Perform portogram to ensure catheter is sufficiently selective to prevent nontarget embolization
- Deliver embolic agent until stasis is achieved: Cyanoacrylate or permanent particles most commonly used
    - N-butyl cyanoacrylate
        - Requires very strict technique
        - Mixed with Lipiodol for radiopacity; glue more slowly solidifies with increased Lipiodol volume (e.g., 5:1 Lipiodol:glue ratio)
        - 5% glucose flush before/after injection; prevents cyanoacrylate polymerization in catheter
    - Permanent particles: Start with smaller particles to obtain distal and complete embolization, then increase particle size in stepwise fashion to occlude centrally (limiting total number of particle vials needed)
        - Some centers place coils distally in portal branches after small & medium particle embolization
    - Strive to achieve complete distal embolization of target branch; incomplete PVE can result in inadequate hypertrophy of nontarget lobe prior to planned surgical resection
- Obtain completion portogram after embolization
- Remove catheter and sheath
    - Consider prophylactic tract embolization

Findings and Reporting

- Describe approach used (ipsilateral vs. contralateral)
- Note any portal venous anatomy anomalies
- Record embolic agent and branches embolized
- Note hepatic volumetric calculations before PVE

Alternative Procedures/Therapies

- Associating liver partition and PV ligation in staged hepatectomy (ALPPS) strategy
  - Stage I: In situ splitting of liver and PV ligation
    - Splitting prevents tumor spread and collateral PV formation
    - Ligation of portal vein induces FLR hypertrophy
  - Stage II: Hepatectomy
    - Same procedure as performed following PVE
    - Generally occurs within 7 days vs. 6-8 weeks for PVE
  - Comparison to PVE
    - Greater increase in FLR size in less time than PVE
      - Not clear if greater increase in size correlates with increase in hepatic function
      - May reflect postprocedure edema/inflammation
    - More frequent completion of stage II than with PVE
      - Mostly due to shorter duration between 1st and 2nd stage, preventing interval tumor growth
    - Double mortality after stage II than PVE (14% vs. 7%)
    - Higher complication rates than PVE
  - May offer alternative approach in case of preexisting portal vein thrombosis or invasion
- Portal vein ligation (without liver partition)
  - Similar to PVE with respect to FLR hypertrophy and completion of stage II but requires invasive procedure
    - Increased mortality after stage II vs. PVE (9% vs. 7%)
    - Slightly higher rates of complication vs. PVE

POST PROCEDURE

Things To Do

- Order bedrest for 2-4 hours
- Monitor for potential postembolic symptoms (e.g., pain, nausea) and treat appropriately
- Monitor for signs of procedure-related complications: Subscapular hematoma, hemobilia, hemoperitoneum, pneumothorax, cholangitis
- Reasonable to admit patients overnight, although some institutions discharge same day
- Schedule CT/MR with hepatic volumetric calculations ~ 4 weeks after PVE (but prior to surgery)
  - Calculate FLR volume after PVE
  - Calculate DH and KGR

OUTCOMES

Problems

- Insufficient FLR hypertrophy
  - More common in patients with underlying cirrhosis
  - Can perform segment IV embolization (if not already completed) or ipsilateral hepatic vein embolization for further FLR hypertrophy
- Interval local tumor progression preventing resection, even with adequate FLR hypertrophy
  - Increased primary tumor size due to hepatic arterial supply
    - TACE can be done after PVE to reduce tumor burden
  - Increased size of tumor in nonembolized segments (usually segment IV) due to redirection of flow
    - May prevent by embolizing segment IV branches at time of initial PVE
    - Can also do TACE after PVE to reduce tumor burden

Complications

- Most feared complication(s)
  - Nontarget embolization or thrombosis (0.6-0.8%)
  - Hemodynamically significant hemorrhage (< 1%)
- Immediate/periprocedural complication(s)
  - Minor complications (11% overall)
    - Fever (37%); abdominal pain (20-30%)
  - Major complications
    - Hemobilia (2%)
    - Subcapsular hematoma, infection, bile leak (< 1% each)
- Increased complication rate if DH < 5% or KGR < 2%

Expected Outcomes

- Technically successful PVE in nearly 100% of cases
- Transient transaminitis in up to 35%
- Average FLR volume increase of 30-45% at 30 days
- Hepatic resection able to be performed in 85-90%
  - May decrease to 70% in those with cirrhosis

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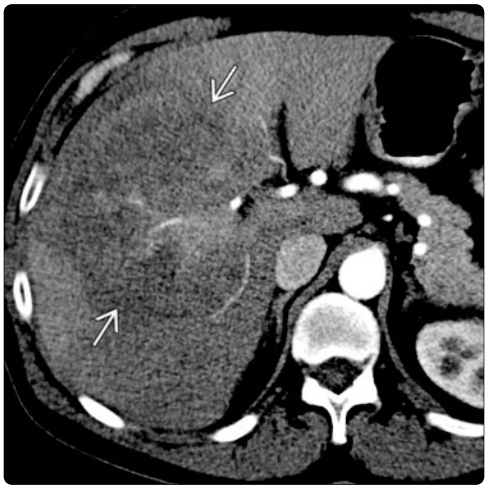
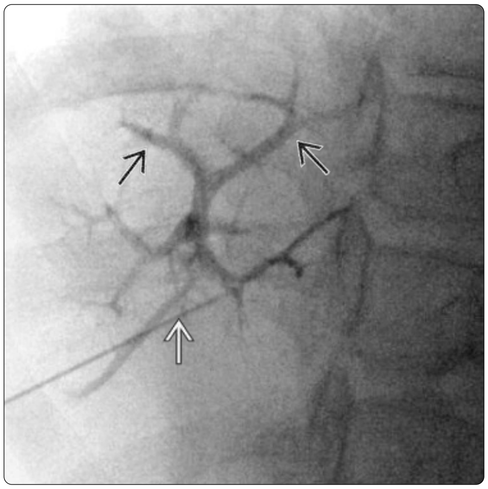
(Left) *Axial CECT shows a large right hepatic HCC ➡ without evidence of portal vein invasion. The patient was recommended for right hepatectomy; however, analysis of the right and left hepatic lobes indicated the FLR would be < 20% of the total liver volume.* **(Right)** *An ipsilateral embolization approach through the tumor-bearing liver was used for portal vein embolization. Contrast injection through a 22-g Chiba needle ➡ opacifies branches of the right portal system ⇨.*

Right PVE: Preprocedural Imaging (Diagnostic CT)

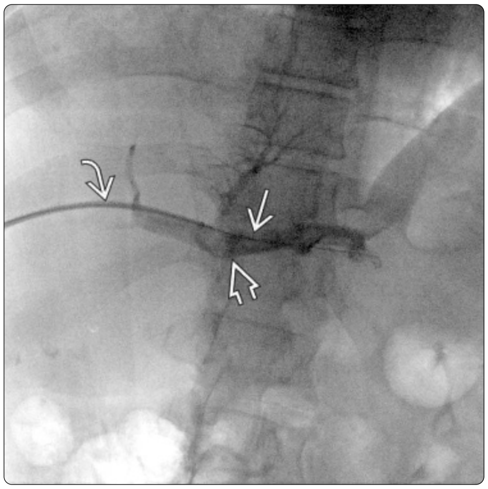


Right PVE: Ipsilateral Technique (Portal Venogram)

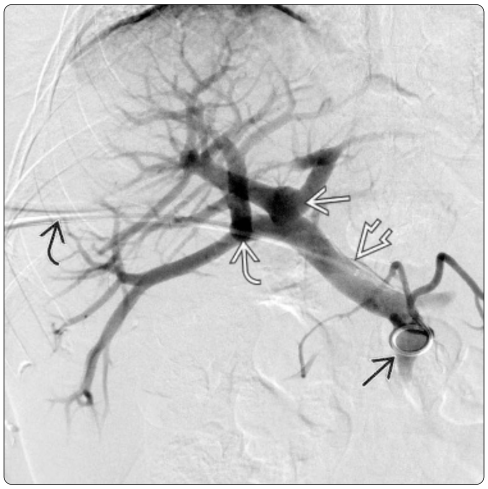


(Left) *A Chiba needle was exchanged for coaxial introducer sheath ➡, through which a 0.035" guidewire ➡ was advanced centrally. Contrast injection shows the more central ➡ portal anatomy.* **(Right)** *A 6-Fr access sheath ⇨ was placed, and a pigtail catheter ⇨ was advanced into the main portal vein ➡. Portogram clearly shows the left ➡ and right ➡ portal veins.*

Right PVE: Ipsilateral Technique (Coaxial Access)

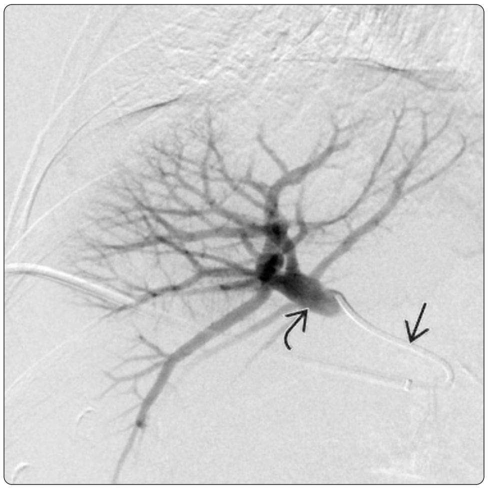


Right PVE: Ipsilateral Technique (Main Portal Venogram)

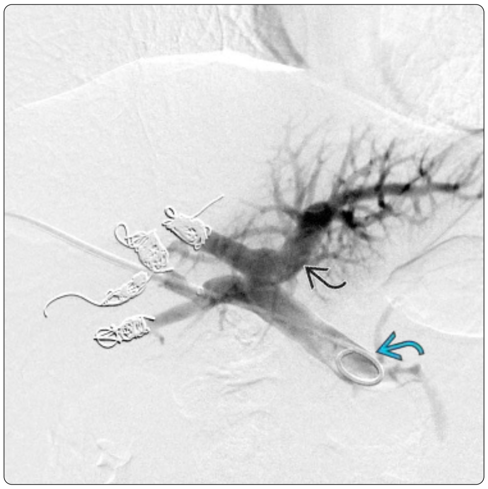


(Left) *The pigtail was replaced with a reverse-curve catheter ⇨ used to selectively catheterize the right portal vein branches ⇨ supplying segment VII. Particle embolization using 300-500 µm Embospheres was performed.* **(Right)** *After embolization of the portal vein branches supplying segments VI-VIII (via a combination of particles and coils), a portogram was performed. The pigtail catheter ⇨ remains in the patent main portal vein. The left portal vein ⇨ remains patent.*

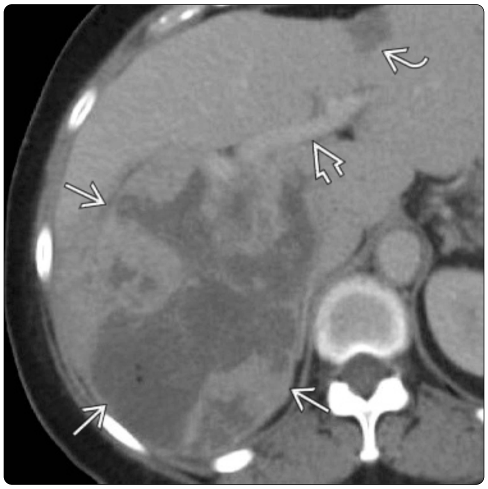
Right PVE: Ipsilateral Technique (Magnified View)



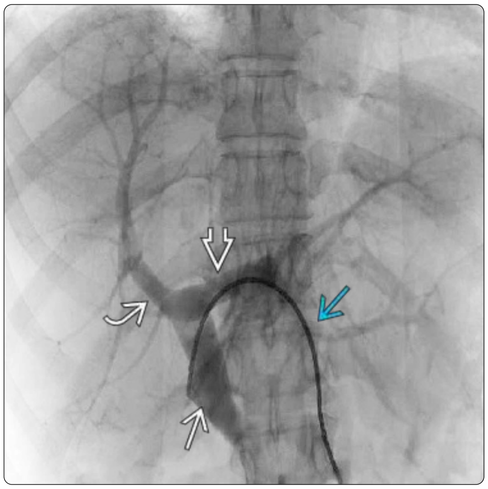
Right PVE: Ipsilateral Technique (Final Portal Venogram)



Right PVE: Preprocedural Imaging (Diagnostic CT)

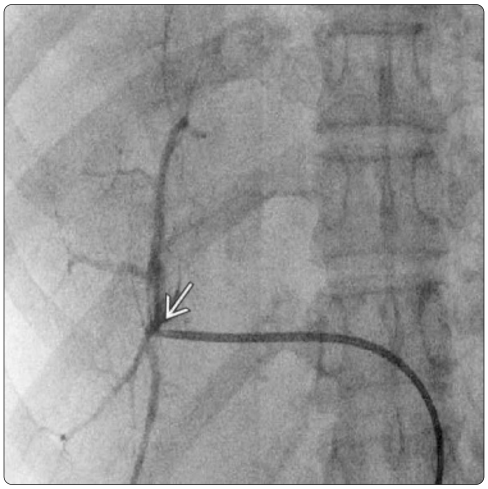


Right PVE: Contralateral Technique (Portal Venogram)

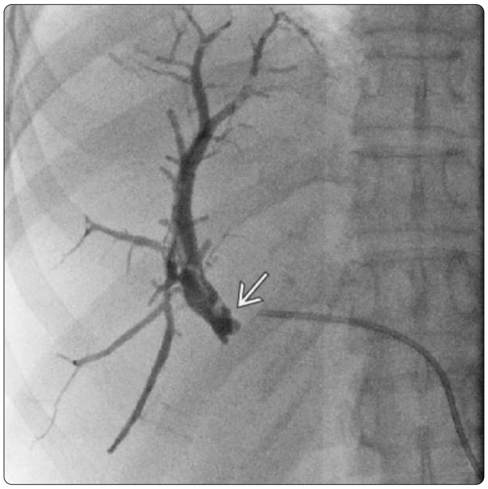


(Left) *Axial CECT shows a large, right, biopsy-proven fibrolamellar carcinoma ➔. The left portal vein ➔ is patent. Incidentally, a left hepatic lobe hemangioma ➔ is also seen. The patient was referred for PVE prior to right hepatectomy.* **(Right)** *Segment III portal vein access ➔ was obtained, and a vascular sheath was advanced into the main portal vein ➔. Note left main ➔ and right anterior division portal veins ➔. The posterior division was known to be occluded via extrinsic compression from the right hepatic mass.*

Right PVE: Contralateral Technique (Right Portal Venogram)

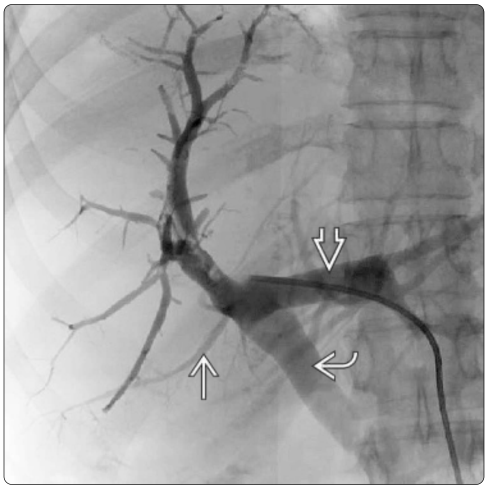


Right PVE: Contralateral Technique (Glue Embolization)

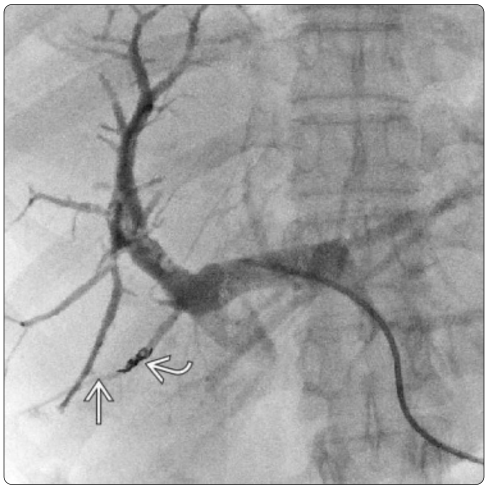


(Left) *Subselection of the distal right portal vein ➔ with a microcatheter was performed. Due to contralateral technique, a reverse-curve catheter did not need to be used.* **(Right)** *Embolization with glue was performed through the microcatheter. Postembolization image shows the radiopaque glue extends back to the proximal right portal vein ➔ without spilling into the main or left portal veins.*

Right PVE: Contralateral Technique (Patient Segment VI)



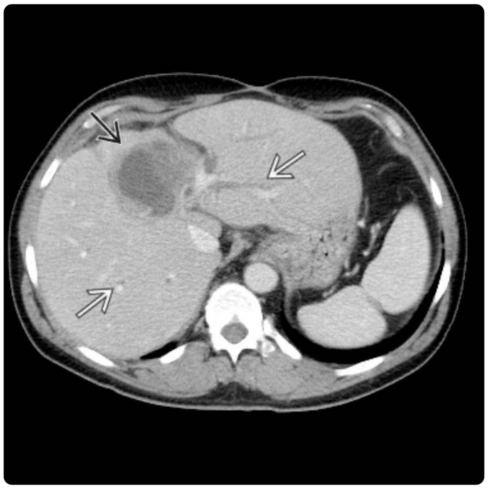
Right PVE: Contralateral Technique (Coil Embolization)



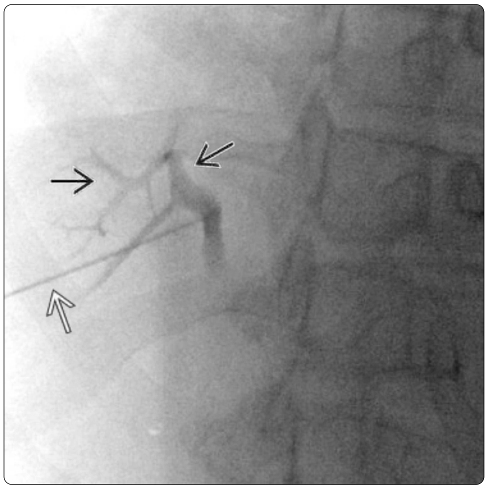
(Left) *Subsequently, portogram confirms patency of the left ➔ and main ➔ portal veins but also shows persistent opacification of a segment VI portal venous branch ➔ supplying part of the posterior right hepatic lobe.* **(Right)** *Following glue embolization of the distal segment VI portal venous branch ➔, coils ➔ were also deployed proximally; it was believed that further proximal delivery of glue in this branch would risk nontarget embolization of the adjacent left or main portal veins.*

(Left) *Axial CECT shows a large neuroendocrine tumor ⇨ with extension into the left hepatic lobe. The patient was referred for PVE prior to left hepatectomy. While FLR measured ~ 40%, the patient had previously received chemotherapy. Biliary dilation ⇒ was present due to mass effect.* **(Right)** *Contralateral embolization approach was used for PVE. Contrast injection through a 22-g Chiba needle ➡ opacifies branches of the right portal system ⇨. The needle was exchanged over a wire for a coaxial introducer sheath.*

Left PVE: Preprocedural Imaging (Diagnostic CT)

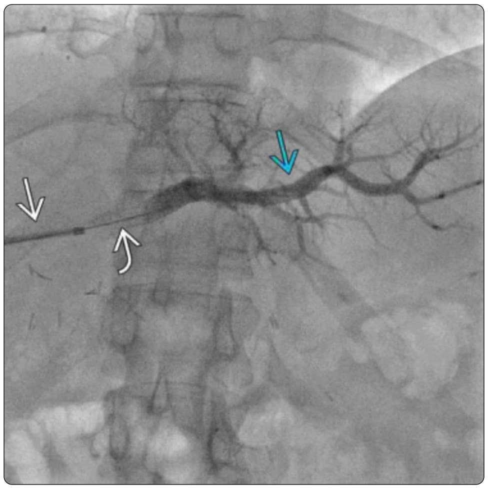


Left PVE: Contralateral Technique (Right Portal Access)

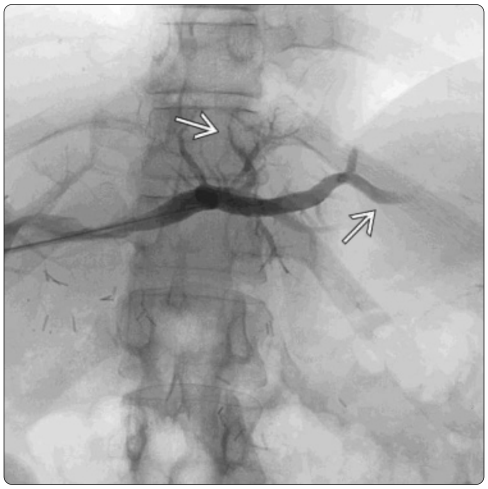


(Left) *Through this sheath, a 0.035" wire ↪ was advanced across the portal bifurcation into the left portal vein. Ultimately, a 6-Fr vascular sheath ➡ was placed. This was advanced to the bifurcation and left portal venogram ⇨ was performed.* **(Right)** *Following particle embolization of the left portal vein with 300-500 µm Embospheres through a 5-Fr catheter, a repeat left portal venogram was performed. Near stasis was achieved with pruning of the segmental and subsegmental branches ➡.*

Left PVE: Contralateral Technique (Left Portal Venogram)

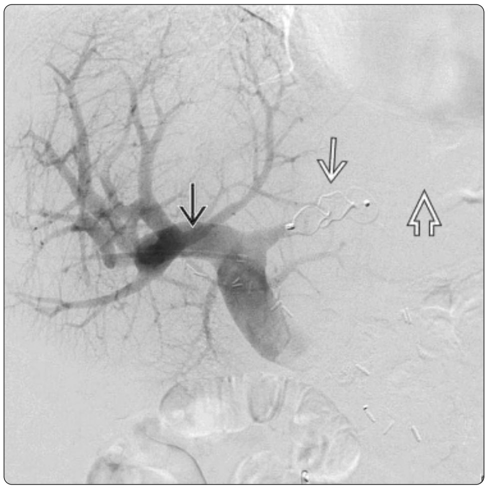


Left PVE: Contralateral Technique (Left Portal Embolization)

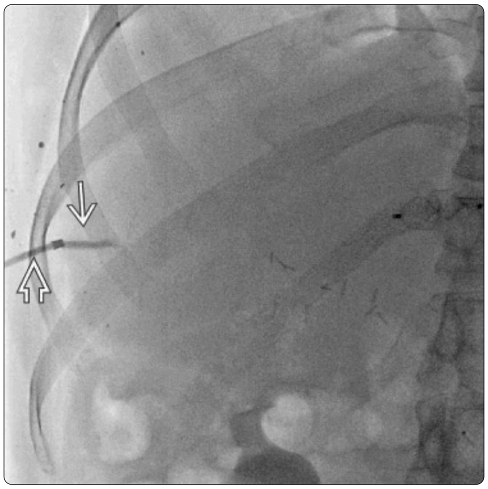


(Left) *Following particle embolization, a 16-mm Amplatzer vascular plug ➡ was placed in the proximal left portal vein through the 6-Fr sheath. Repeat portography demonstrates no flow in the left portal vein ⇒ beyond the plug. The right portal vein ⇨ remains widely patent.* **(Right)** *Upon completion of the procedure, embolization of the hepatic parenchymal tract was performed with a contrast-filled Gelfoam torpedo ➡ administered through the sheath ⇒ as it was withdrawn.*

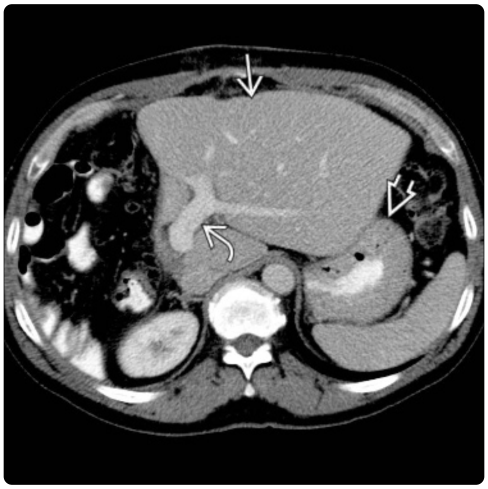
Left PVE: Contralateral Technique (Final Portal Venogram)



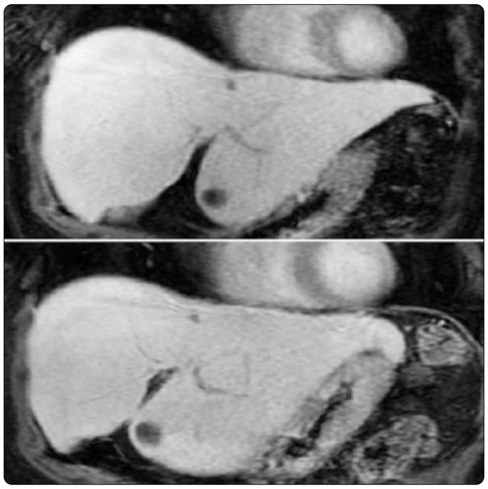
Left PVE: Contralateral Technique (Tract Embolization)



Postsurgical CT

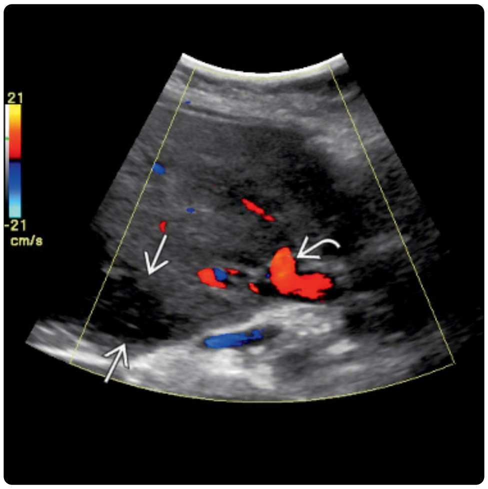


FLR Hypertrophy

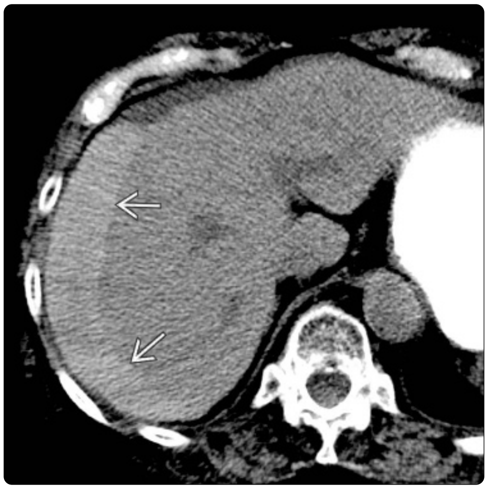


(Left) *Axial CECT after right hepatectomy shows an enlarged, normally enhancing left hepatic lobe ➡ with a normal left portal vein ↪. The hypertrophied left lobe displaces the stomach ⇨ posteriorly.* **(Right)** *Evaluation of left hepatic lobe before (top) and after (bottom) right PVE shows hypertrophy of the left hepatic lobe, which allowed the patient to undergo right hepatectomy.*

Arterial Hemorrhage After Ipsilateral Portal Vein Embolization (US)

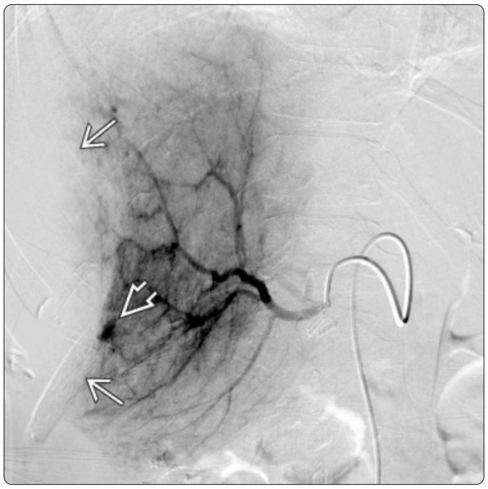


Arterial Hemorrhage After Ipsilateral Portal Vein Embolization (US)

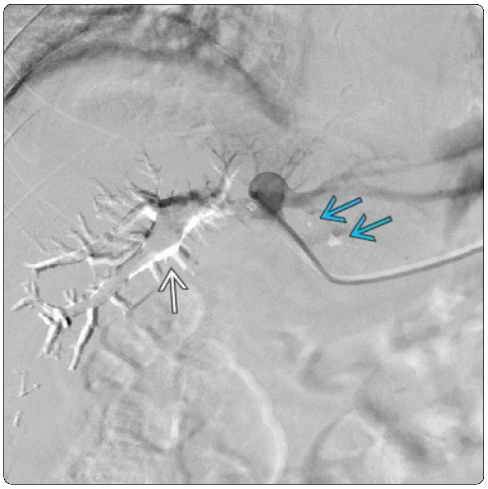


(Left) *Sagittal color Doppler US, obtained in a patient who developed worsening right upper quadrant pain following right PVE from an ipsilateral approach, shows a right hepatic subcapsular hematoma ➡. The main portal vein ↪ and proximal branches are widely patent.* **(Right)** *Axial NECT shows a high-attenuation subcapsular hematoma ➡ that occurred following a right PVE using ipsilateral access. Because of hemodynamic instability, further evaluation with angiography was indicated.*

Arterial Hemorrhage After Ipsilateral Portal Vein Embolization



Nontarget Complication of Portal Vein Embolization



(Left) *Hepatic DSA shows the avascular area ➡ of the subcapsular hematoma, displacing the hepatic parenchyma medially. Focal contrast extravasation ⇨ from a peripheral hepatic arterial branch was present, subsequently controlled with transcatheter embolization.* **(Right)** *Digitally subtracted portogram following glue embolization of the right portal vein ➡ is shown. Noted are 2 small subtraction artifacts ⇨ overlying segment III of the left hepatic lobe consistent with nontarget embolization.*

Portal and Hepatic Venous Thrombosis

KEY FACTS

TERMINOLOGY

- **Portal vein thrombosis (PVT)**: Acute or chronic, complete or partial occlusion of portal vein ± extension into mesenteric or splenic veins
  - Cirrhosis (28%)
  - Abdominal malignancy (27-44%)
  - Inherited thrombophilia (20%)
  - Myelodysplastic syndrome (11%)
  - Inflammatory process (10%)
- **Hepatic vein thrombosis (HVT)**: Acute or chronic, complete or partial occlusion of hepatic veins ± extension into inferior vena cava
  - Usually secondary to Budd-Chiari syndrome
  - Often also associated with other underlying thrombotic state (inherited or acquired)
- **Clinical presentation**
  - Acute: RUQ pain, ascites, bowel ischemia, sepsis
  - Chronic: Features of portal hypertension, varices

PREPROCEDURE

- Indications: Symptomatic PVT/HVT/occlusion with
  - Worsening of symptoms despite systemic anticoagulation
  - Concern for imminent bowel ischemia/infarct
  - Concomitant planned transjugular intrahepatic portosystemic shunt (TIPS) creation

PROCEDURE

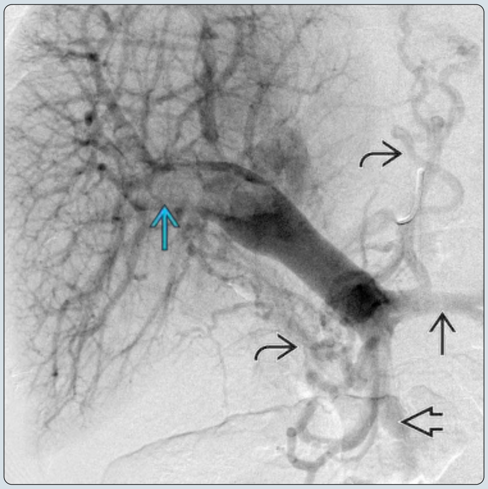
- Venous access: Percutaneous transhepatic or TIPS style
- Mechanical thrombolysis &/or pharmacologic catheter directed thrombolysis
- Additional procedures
  - Angioplasty/stenting of underlying stenosis
  - TIPS creation

POST PROCEDURE

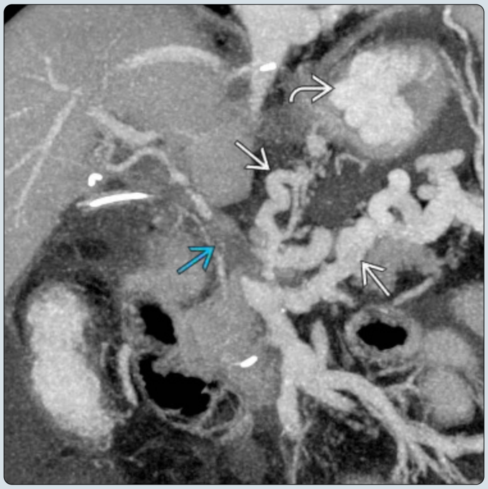
- Strongly consider systemic anticoagulation
- Diagnose/treat etiology of PVT

(Left) *The portal phase of a superior mesenteric arteriogram reveals a large portal venous thrombus* ⇨*. The splenic* ⇨ *and superior mesenteric* ⇨ *veins remain patent. Enlarged collateral veins* ↷ *are present.* **(Right)** *Chronic thrombosis has resulted in portal vein occlusion* ⇨*. Subsequently, a spontaneous portosystemic shunt* ➡ *(with gastric varices* ↷*) has formed. Reestablishing portal patency can decompress the varices by providing mesenteric venous outflow, thereby reducing the risk of variceal bleeding.*

Portal Vein Thrombus

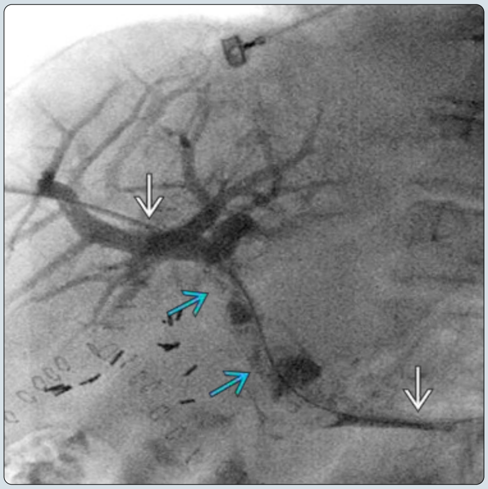


Chronic Portal Venous Thrombosis

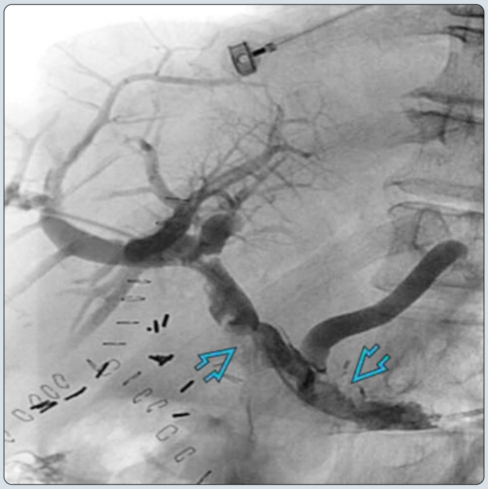


(Left) *Portal venography in a patient with recent liver transplantation reveals extensive filling defects within the main portal vein* ⇨*. An infusion catheter* ➡ *was advanced into the portal system via percutaneous transhepatic approach, traversing the thrombus.* **(Right)** *Portal venogram following 12 hours of catheter-directed thrombolysis demonstrates partial interval recanalization of the main portal vein with some residual filling defects* ⇨*. Infusion of tPA was continued for an additional 12 hours.*

Portal Vein Thrombolysis (Infusion Catheter Placement)



Portal Vein Thrombolysis (Post Catheter-Directed Thrombolysis)



TERMINOLOGY

Definitions

- **Hepatic venous outflow obstruction**
  - 3 categories based on level of obstruction
    - Venoocclusive disease: Sinusoids and terminal venules
      - Toxin-induced nonthrombotic obstruction; often occurs after stem cell transplant, chemotherapy, or radiotherapy
    - Budd-Chiari syndrome (BCS)
      - Pain, ascites, liver enlargement caused by hepatic vein occlusion
    - Congestive hepatopathy
      - Passive hepatic congestion, usually related to right heart failure (e.g., tricuspid regurgitation, cor pulmonale)
  - Associated problems of hepatic venous outflow obstruction
    - Cirrhosis, portal hypertension (HTN), hepatic/portal vein thrombosis
- **Hepatic vein thrombosis (HVT)**: Acute or chronic, complete or partial occlusion of hepatic veins ± extension into inferior vena cava (IVC)
  - Usually due to BCS
    - Primary
      - Intraluminal thrombosis or webs
      - Atypical myeloproliferative disease present in 50%
      - Etiologies also include pregnancy, polycythemia vera, Behçet disease, paroxysmal nocturnal hemoglobinuria
    - Secondary
      - Nonthrombotic; intraluminal invasion (e.g., tumor) or extraluminal compression
  - Can lead to portal HTN and related complications
- **Portal vein thrombosis (PVT)**: Acute or chronic, complete or partial occlusion of portal vein ± extension into mesenteric or splenic veins
  - Local causes
    - Cirrhosis (28%)
    - Abdominal malignancy (27-44%)
    - Inflammatory conditions (10%) (e.g., diverticulitis, pancreatitis, appendicitis, inflammatory bowel disease)
    - Intraabdominal infection
    - Portal vein injury
  - Systemic causes
    - Inherited thrombophilia (20%) (e.g., factor V Leiden, prothrombin mutation)
    - Acquired thrombophilia
      - Myelodysplastic syndrome (11%)
      - Others: Pregnancy, hormone use (including oral contraceptive pills), antiphospholipid syndrome, etc.
  - Mortality rates without treatment; justify risk of endovascular treatment after failed anticoagulation
    - < 10%: Chronic PVT in patient without cirrhosis or malignancy
    - 26%: Chronic PVT in patient with cirrhosis &/or malignancy
    - 20-50%: Acute PVT with evidence of bowel ischemia/infarct
- **Clinical presentation**
  - Acute thrombosis: Spectrum depends on severity
    - Right upper quadrant tenderness ± hepatomegaly
    - Jaundice, ascites
    - Findings of bowel ischemia/infarction with PVT
      - Abdominal pain
      - Nausea, vomiting, diarrhea
      - Fever, sepsis
  - Chronic thrombosis: Symptoms related to portal HTN
    - Ascites
    - Development of varices ± bleeding
    - Splenomegaly

PREPROCEDURE

Indications

- Symptomatic PVT/HVT with
  - Failed systemic anticoagulation
  - Concern for imminent bowel ischemia/infarct
    - Usually in case of mesenteric vein involvement
  - Need for concomitant transjugular intrahepatic portosystemic shunt (TIPS) creation
- Complications of portal HTN caused by chronic PVT/HVT
  - Usually due to uncontrolled/recurrent variceal bleeding
    - Recanalization of portal/hepatic vein restores in-line flow, decompressing varices, and reducing bleeding risk

Contraindications

- Contraindications to pharmacologic thrombolysis
  - Active hemorrhage or potential for bleeding
  - Surgery in previous 10 days
  - Neurosurgery in previous 3 weeks
  - Intracranial process (e.g., recent cerebrovascular accident, neoplasm)
  - Recent trauma
- Evidence of extensive bowel infarction or septic shock
- Ascites is relative contraindication
  - Perform paracentesis before transhepatic access
- Uncorrectable bleeding disorders

Preprocedure Imaging

- **US**
  - Echogenic thrombus in vein lumen
    - Absent flow inside vein lumen
  - Doppler US shows venous anatomy/collaterals
- **CT or MR**
  - Thrombus appears hypodense post contrast
    - Surrounding vein wall enhancement
  - Heterogeneous hepatic enhancement in BCS
    - Early enhancement of enlarged caudate lobe; decreased liver enhancement peripherally
    - Clearly defined areas of hypodensity corresponding to thrombosed hepatic veins
  - Unlike US, allows for better evaluation of
    - Extension of thrombus into splenic vein, mesenteric vein, or IVC
    - Underlying causative etiology (malignancy, inflammatory process, etc.)
    - Related complications, including bowel ischemia/infarction

Getting Started

- Things to check
  - Clinical history and physical examination
    - Procedure indications
    - Signs or symptoms of extensive bowel necrosis, perforation, or septic shock
      - Surgical exploration/resection required
  - Allergies
  - Labs and medications based upon procedure having "significant risk of bleeding" per Society of Interventional Radiology (SIR) consensus guidelines
    - Labs
      - Complete blood count (CBC): Platelet count > 50,000/μL
      - International normalized ratio (INR) ≤ 1.5 preferred
    - Medications
      - Ticlopidine: Withhold for 7 days before procedure
      - Aspirin and clopidogrel: Withhold 5 days before procedure
      - Dabigatran and fondaparinux: Withhold 2-3 days before procedure (or 3-5 days if CrCl < 50 mL/min)
      - Low molecular weight heparin (therapeutic): Withhold for 24 hours before procedure or up to 2 doses
      - Heparin (unfractionated): Withhold for 2-4 hours before procedure
    - Electrolytes, glomerular filtration rate (eGFR)
    - Liver function tests
  - Review of cross-sectional imaging
    - Extent of venous thrombosis: Partial/complete, segment length
    - Venous anatomy: Anomalies, collaterals, varices
    - Absence/presence of ascites
    - Evidence of extensive bowel infarction
  - Informed consent: Specific considerations
    - Hemorrhage: Potentially life threatening
      - Local: Intraperitoneal, subcapsular, access site hematoma
      - Others: Hemothorax, hematuria, epistaxis, etc.
    - Technical failure to recanalize vessel or prevent bowel ischemia/infarct
    - Rethrombosis (despite initial technical success)
    - Abdominal pain, nausea, transaminitis
- Medications
  - Antibiotic prophylaxis
    - SIR guidelines: Routinely recommended in case of transhepatic access; no consensus on 1st-line agent
    - Should cover *Staphylococcus aureus*, *S. epidermidis*, *Enterococcus*, *Streptococcus*, gram negatives, anaerobes
  - Intravenous (IV) heparin
    - Administer after access but prior to thrombolysis
    - Administered via peripheral IV or transcatheter
      - Typically 2,000-5,000 U bolus, then 500-800 U/h infusion
  - Tissue plasminogen activator (tPA)
    - 1 mg/h with catheter-directed thrombolysis (CDT)
    - Up to 10 mg intrathrombotic bolus prior to CDT or during pharmacomechanical thrombolysis
  - Anesthesia: Moderate or general

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Transjugular access (TIPS style)
    - Technically more demanding
    - Provides access for TIPS creation, if desired
  - Percutaneous transhepatic access
    - Direct access to portal or hepatic veins
    - Requires traversal of hepatic capsule, increasing risk of hemorrhage

Procedure Steps

- **Venous access**
  - Perform preprocedure US of access site
  - Sterilely prep and drape access site
  - Administer 1% lidocaine at skin access point and along any subcutaneous tract
  - Obtain access into venous system (hepatic or portal)
    - Percutaneous transhepatic venous access
      - Use US (Doppler assisted) to target venous system, determine safe route of access
      - Percutaneously access venous system with US-guided advancement of 21- to 22-g Chiba needle; may target either portal vein or hepatic vein using this method
      - Inject contrast via needle, advance 0.018" wire (Nitrex works well)
      - Use fluoroscopic guidance for wire advancement and access if US guidance fails
    - Transjugular TIPS-style access
      - Use US guidance to access right internal jugular vein
      - Negotiate 0.035" guidewire through vena cava into hepatic vein
      - Continue portography and intrahepatic access of portal system if needed
  - Following initial access into venous system
    - Remove needle and place coaxial introducer sheath
    - Exchange for 0.035" guidewire via sheath
    - Place 5- to 7-Fr access sheath
- **Diagnostic venography**
  - Portogram: Determine thrombus location and extent into splenic vein or superior mesenteric vein (SMV)
  - Hepatic venogram/cavogram: Determine thrombus location and extent into IVC
  - Estimate chronicity of thrombus (acute, subacute, chronic); may alter treatment
  - Advance guidewire and catheter across thrombus
    - Repeat venography to determine extent of thrombus, distal vessel patency, and collateral flow
- **Thrombolysis**
  - CDT
    - Position infusion catheter/sheath across thrombus so that proximal and distal portions of catheter are within patent vein
      - Bolus 5-10 mg tPA through infusion catheter (optional)
      - Infuse tPA at 0.5-1 mg/h through catheter
      - Infuse heparin at 500 U/h through sheath after initial bolus

      - Monitoring patient in ICU
      - Obtain CBC, INR, fibrinogen every 4-8 h
      - Stop tPA infusion if fibrinogen < 150 mg/dL, mental status changes occur, or clinical signs of active bleeding develop
      - Continue CDT for 6-24 h, then reevaluate
    - Evaluate progression of lysis
      - Perform venogram to assess response to therapy, presence of residual clot
      - If residual thrombus, can continue CDT or switch to mechanical thrombolysis as clinically appropriate
  - Pharmacomechanical thrombolysis
    - Consider in case of extensive thrombosis
      - Debulks clot before CDT or cases in which CDT not possible
      - Achieves faster resolution of thrombosis, which permits lower thrombolytic agent dose
    - Deliver systemic anticoagulation (e.g., IV heparin) prior to mechanical thrombolysis
    - Infuse thrombolytic agent directly into thrombus
    - Mechanics available
      - Rotational-device maceration of thrombus
      - Balloon maceration of thrombus
      - Pulse-spray tPA into thrombus
      - Possis AngioJet thrombolysis
      - Suction aspiration via 6- to 10-Fr sheath
    - Possible protocol
      - Gain access, deliver IV heparin of 4,000-5,000 U
      - Place infusion catheter across thrombus
      - Semiforcefully inject 5-10 mg tPA locally and wait 15-30 min
      - Macerate clot with balloon angioplasty or rotational device
      - Perform thromboaspiration via sheath/catheter
      - Initiate CDT
- **After thrombolysis**
  - Angioplasty or stenting of underlying stenosis
    - Residual stenosis, even without visible clot, will predispose patient to rethrombosis due to associated venous stasis
  - Evaluate need for TIPS (proceed if indicated)
    - Portal venous thrombosis in patients with underlying decompensated cirrhosis and portal HTN
    - Hepatic venous thrombosis in patients with advanced BCS
    - Bridge to liver transplantation
  - Procedure completion
    - Remove catheter/sheaths over wire
    - For percutaneous transhepatic access, consider Gelfoam embolization of tract
  - Strongly consider restarting systemic anticoagulation

Alternative Procedures/Therapies

- Radiologic
  - Indirect thrombolysis via superior mesenteric artery
    - Infusion of tPA via multiple sidehole catheter placed selectively in superior mesenteric artery
      - Thrombolytic agent theoretically circulates into entire portal venous system
      - May bypass thrombus entirely via collaterals
    - Compared to direct PV/SMV thrombolysis
      - Decreased technical success: Recanalization rates of 50% vs. > 90%
      - Prolonged infusion times (several days) with increased complication rates
    - Consider as alternative if direct portal venous access cannot be obtained
- Surgical
  - Intraoperative thrombectomy
    - Indicated for cases with signs of bowel infarction requiring resection
    - No benefit over endovascular intervention if no need for bowel resection
  - Liver transplant in advanced BCS
- Other
  - Systemic anticoagulation: 40-50% clinical success in acute thrombosis
    - Efficacy decreases if not initiated within 1 week
    - May be used to prevent new thrombus or thrombus propagation in case of chronic thrombosis but will not result in recanalization

OUTCOMES

Complications

- Most feared complication(s)
  - Death: Usually due to hemorrhagic complications
  - Complications related to transhepatic puncture
    - Significant intraperitoneal/subcapsular bleeding
      - Can reduce risk with tract embolization
- Immediate/periprocedural complication(s)
  - Reported overall complication rate for PVT: 9-60%
    - Most major complications are related to bleeding
      - Intraperitoneal hemorrhage
      - Subcapsular hematoma
      - Hemothorax, hematuria, epistaxis
    - 15% minor complications
      - Abdominal pain, nausea
      - Transient hepatic encephalopathy and transaminitis
      - Access site complications
  - Lower complication rate for HVT: 5-10%
- Delayed complication(s)
  - Damage to venous endothelium caused by mechanical thrombectomy
    - Increased risk of rethrombosis
  - TIPS-related complications

Expected Outcomes

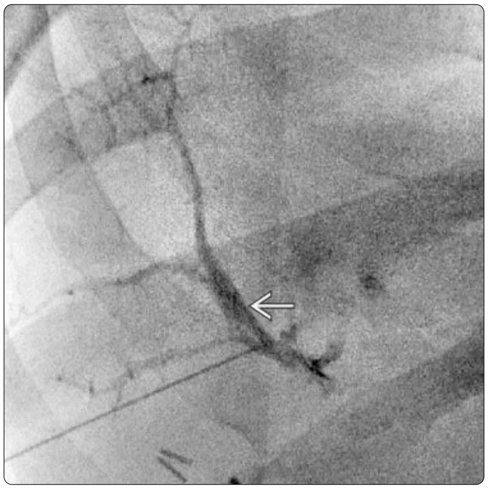
- Prognosis of PVT good when
  - Not due to cirrhosis, malignancy, sepsis
  - Not involving mesenteric veins
- Technical result, acute PVT: Complete recanalization in 40%, partial 45%
- Acute HVT with IVC extension
  - Success rates of 95-100% when combined with IVC stent
  - 85% have complete recanalization
  - 76% with preserved patency at 12-86 months

SELECTED REFERENCES

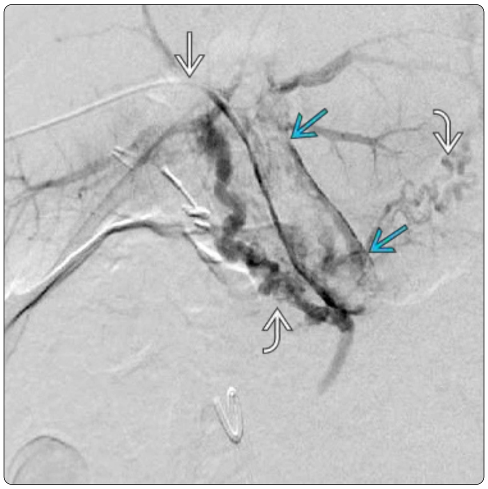
1. Sharma AM et al: Portal vein thrombosis: when to treat and how? Vasc Med. 21(1):61-9, 2016

(Left) *A patient with portal vein thrombosis developed signs of bowel ischemia despite systemic anticoagulation. After reviewing available imaging, percutaneous transhepatic access of the portal system was obtained with a 22-g Chiba needle using ultrasound guidance. An intrahepatic portogram* ➔ *was obtained.* **(Right)** *An AccuStick sheath* ➔ *was advanced into the main portal vein, distended by a large thrombus* ⇨*. Collateral vessels* ➔ *suggest chronicity of the thrombus.*

Step-By-Step: Portal Thrombolysis (Percutaneous Transhepatic Access)

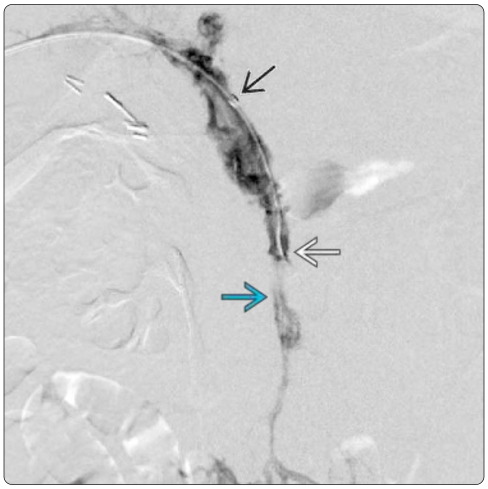


Step-By-Step: Portal Thrombolysis (Portal Venogram)

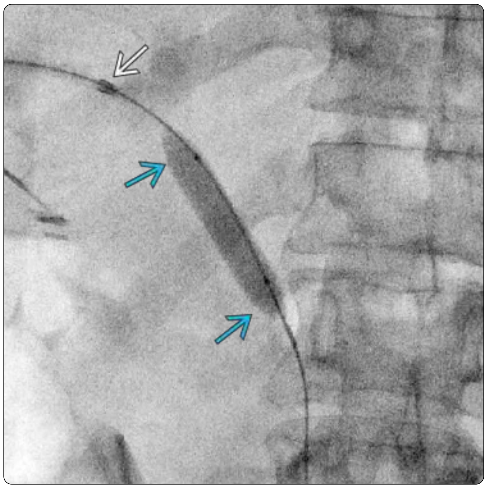


(Left) *A 5-Fr sheath was advanced into the main portal vein* ⇨*. Pharmacomechanical thrombolysis (10 mg tPA, 5,000 U of IV heparin) removed some of the clot; however, a venogram via a catheter advanced into the superior mesenteric vein (SMV)* ➔ *confirmed residual clot extending into the SMV* ⇨*.* **(Right)** *A balloon-mounted catheter* ⇨ *was advanced through the sheath* ➔ *into the main portal vein, and clot maceration was performed throughout the main portal and SMV.*

Step-By-Step: Portal Thrombolysis (Post-Pharmacomechanical Thrombolysis)

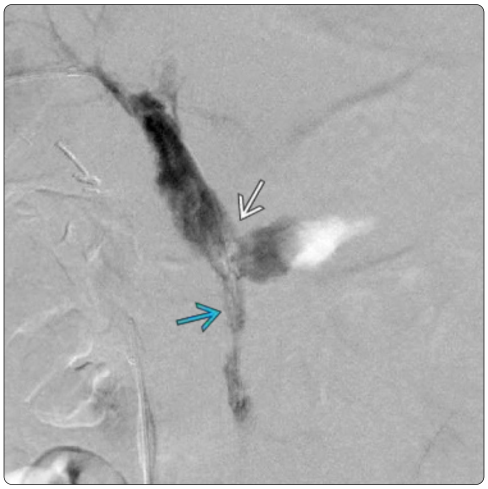


Step-By-Step: Portal Thrombolysis (Balloon Maceration)

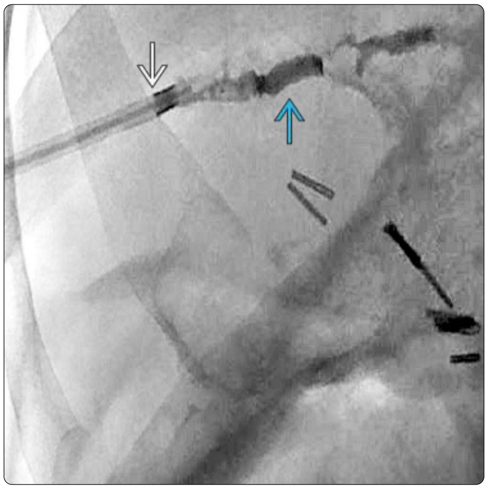


(Left) *Portal venography confirms partial recanalization of both the portal vein* ➔ *and SMV* ⇨*. Depending on the clinical scenario, additional catheter-directed thrombolysis or TIPS creation may be appropriate. Systemic anticoagulation will certainly be necessary in this case.* **(Right)** *There is a high risk of bleeding associated with percutaneous transhepatic access. Parenchymal tract embolization can be performed by deploying contrast-soaked Gelfoam pledgets* ⇨ *as the sheath* ➔ *is withdrawn.*

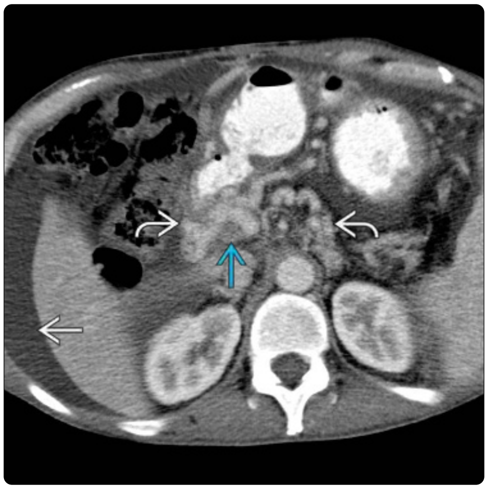
Step-By-Step: Portal Thrombolysis (Consideration of Additional Therapy)



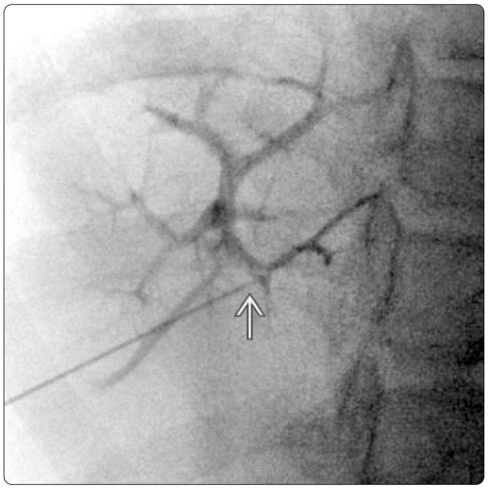
Step-By-Step: Portal Thrombolysis (Tract Embolization)



Step-By-Step: Portal Thrombolysis (Initial Imaging Evaluation)

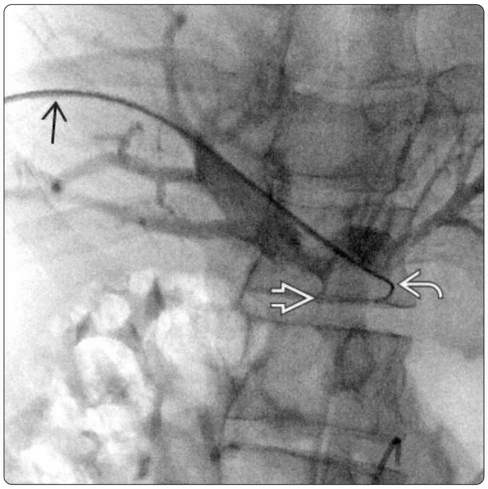


Step-By-Step: Portal Thrombolysis (Transhepatic Portal Vein Access)

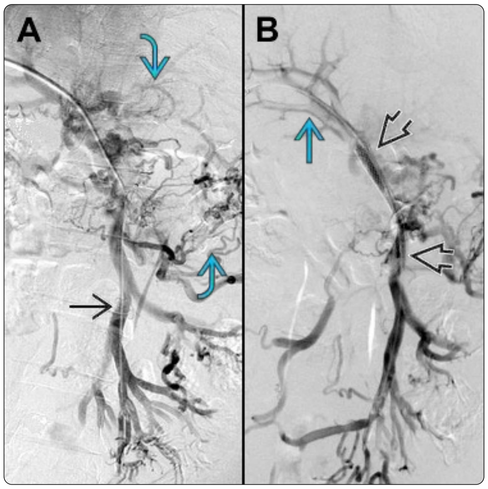


(Left) *In a patient presenting with pancreatic cancer and abdominal pain, CECT reveals a filling defect → in the SMV. Surrounding serpiginous varices ↪ and perihepatic ascites → are also present.* **(Right)** *Percutaneous transhepatic portal venous access was achieved with a 19-g Chiba needle →. Contrast injection demonstrates the needle tip in a right portal vein branch. A normal portal venous branching pattern is seen.*

Step-By-Step: Portal Thrombolysis (Transhepatic Portal Vein Access)

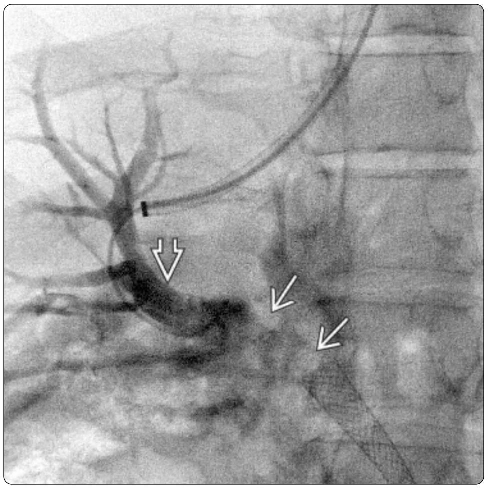


Step-By-Step: Portal Thrombolysis (Stenting and Thrombolysis)

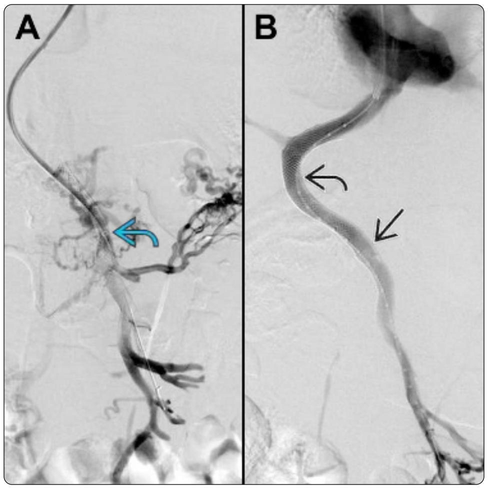


(Left) *A guidewire ↪ and sheath ⇨ were advanced into the main portal vein. Contrast injection shows marked portal vein tapering ⇨ at the SMV level due to thrombosis.* **(Right)** *(A) A guidewire → was advanced across the thrombosed portomesenteric junction into SMV branches. Extensive collaterals ↪ bypass the occlusion. (B) The thrombosed segment was angioplastied and stented ⇨; however, thrombus → was dislodged up into portal venous branches. Access was removed and systemic anticoagulation was initiated.*

Step-By-Step: Portal Thrombolysis (TIPS Creation and Thrombolysis)

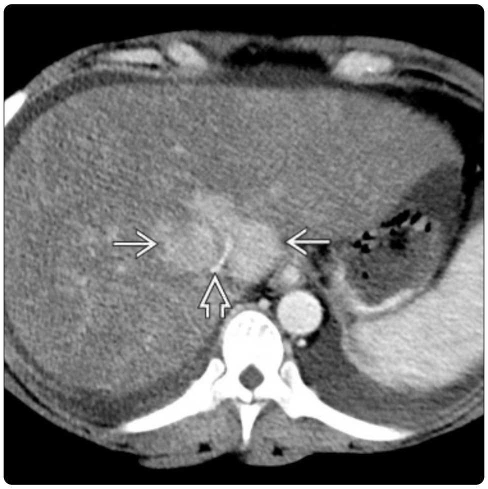


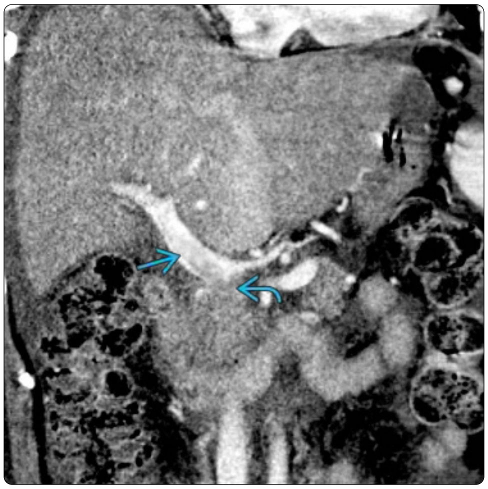
Step-By-Step: Portal Thrombolysis (Post-TIPS Creation and Thrombolysis)



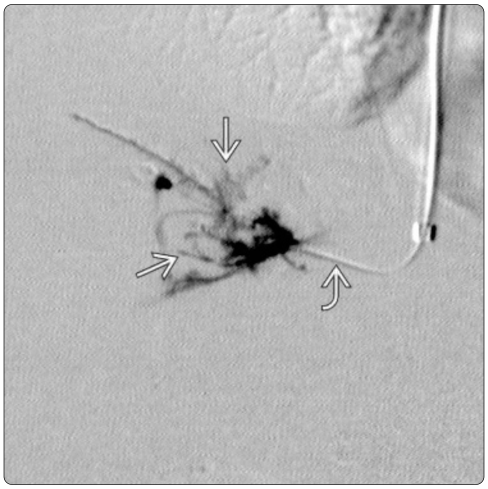
(Left) *After 2 days of anticoagulation, the patient returned for follow-up thrombolysis and TIPS creation. Transjugular access into the portal vein ⇨ shows a persistent filling defect → adjacent to the recently placed SMV stent.* **(Right)** *(A) A sheath ↪ was placed through the occlusion, and pharmacomechanical thrombolysis was performed. (B) After successful thrombolysis, TIPS was created with a stent ↪ extending from the initially placed SMV stent →.*

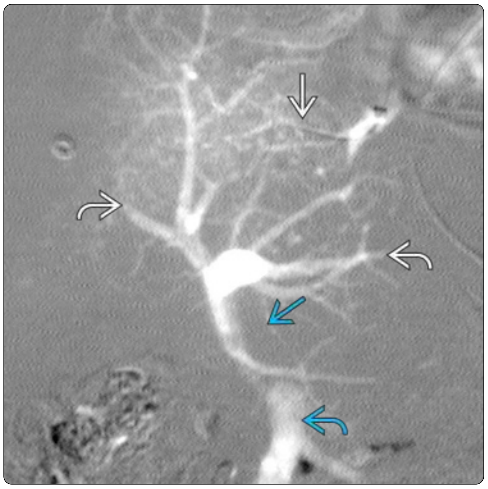
(Left) *Classic Budd-Chiari syndrome findings include hepatomegaly, heterogeneous hepatic enhancement, early enhancement* ➡ *of the caudate lobe, and decreased peripheral hepatic enhancement. In this case, there is marked narrowing of the IVC* ➡. **(Right)** *A filling defect in the main portal vein* → *extends into the SMV* ↪, *consistent with portomesenteric venous thrombosis.*


Budd-Chiari Syndrome and Portal Thrombosis (Axial CECT)

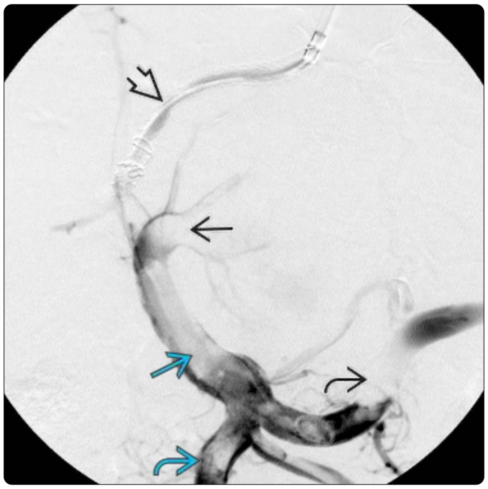

Budd-Chiari Syndrome and Portal Thrombosis (Coronal CECT)

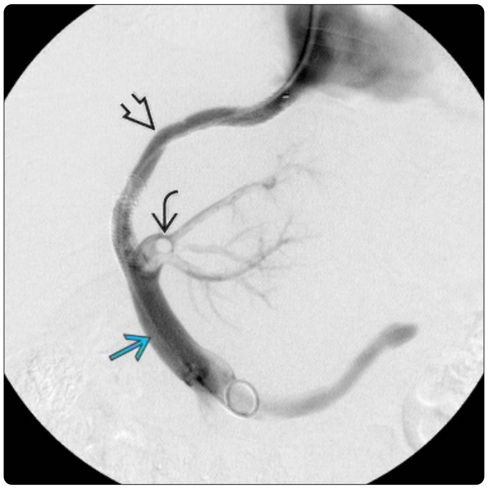
(Left) *TIPS creation and thrombolysis were planned. A catheter* ↪ *was advanced into the hepatic veins via a transjugular sheath. A hepatic venogram shows the "spider web" pattern* ➡ *of collaterals that form around the occluded hepatic veins of patients with Budd-Chiari syndrome.* **(Right)** *A wedged CO_2 portal venogram was obtained using the same catheter* ➡. *A large filling defect* → *in the main portal vein extends into the SMV* ↪. *Intrahepatic portal veins* ↪ *are patent.*


Budd-Chiari Syndrome and Portal Thrombosis (Hepatic Venogram)

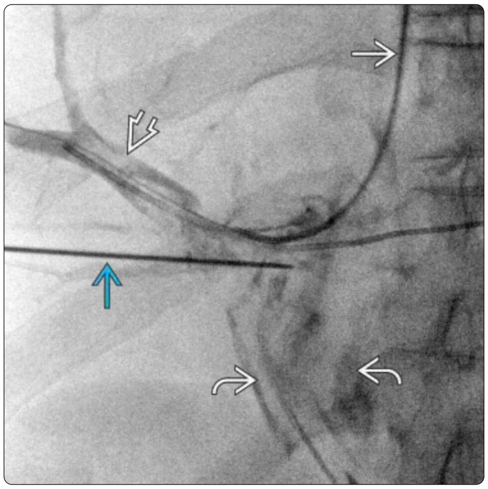

Budd-Chiari Syndrome and Portal Thrombosis (Portal Venogram)

(Left) *A TIPS stent* ⇨ *was deployed and extended to the IVC. Subsequently, portography showed increased thrombus burden* → *within the portal venous system, now extending into left portal vein* ⇨, *the SMV* ↪, *and splenic vein* ↪. **(Right)** *Catheter-directed tPA thrombolysis was performed via the newly created TIPS access. The final venogram shows a patent main portal vein* → *and TIPS stent* ⇨. *Residual thrombus in the left portal vein* ↪ *was treated with systemic anticoagulation.*

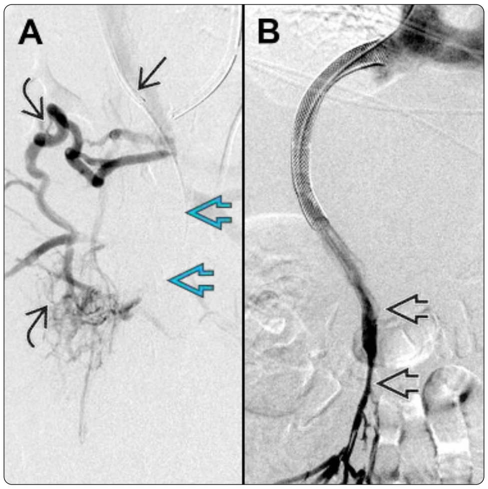

Budd-Chiari Syndrome and Portal Thrombosis (Portal Venogram After TIPS)


Budd-Chiari Syndrome and Portal Thrombosis (Post Thrombolysis)

Transhepatic-Assisted Transjugular Access (Obtaining Access)

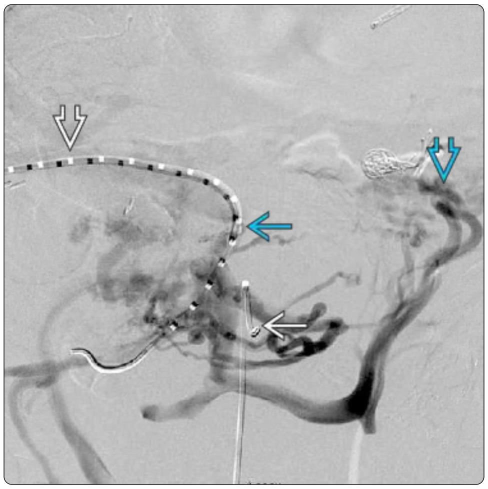


Transhepatic-Assisted Transjugular Access (TIPS Creation and Thrombolysis)

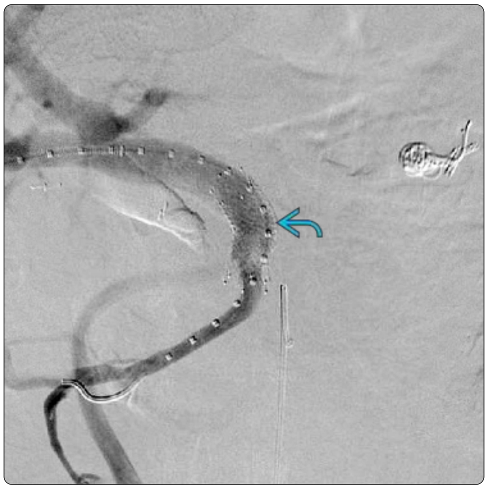


(Left) *Combined transhepatic and transjugular access may be needed in cases of extensive thrombosis. Here, a transhepatic needle → was first used to access a thrombosed portal vein ↪. Injected contrast provided a target for the transjugular catheter →, allowing transhepatic access into a right portal vein ⇨.* **(Right)** *(A) DSA via the TIPS → shows a thrombosed distal SMV ⇨ with drainage via collaterals ↪. (B) SMV ⇨ patency was restored after pharmacomechanical thrombolysis.*

Recurrent Variceal Bleeding (Occluded SMV Resulting in Gastric Varices)

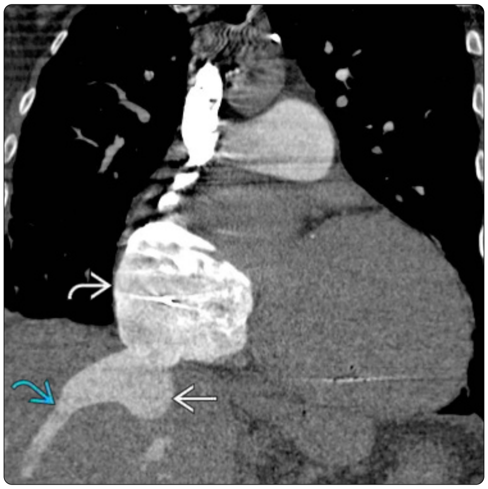


Recurrent Variceal Bleeding (SMV In-Line Flow Restored)

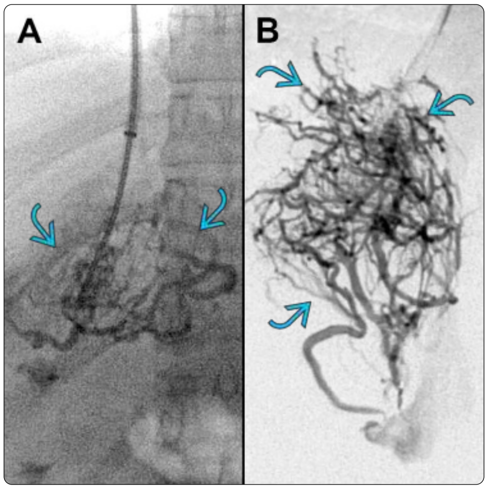


(Left) *With a reverse curve catheter ⇨, a superior mesenteric arteriogram was performed in a patient with known large gastric varices ⇨. The portal vein phase revealed occlusion of the SMV →. A percutaneous transhepatic catheter ⇨ was advanced across the stenosis.* **(Right)** *An endovascular stent ↪ restored in-line flow to the SMV and significantly reduced flow through collateral veins, including the gastric varices. Bleeding from the gastric varices resolved.*

Hepatic Vein Outflow Obstruction (Congestive Hepatopathy)



Hepatic Vein Outflow Obstruction (Venoocclusive Disease)



(Left) *Marked cardiomegaly has resulted in significant reflux of contrast from the right atrium ↪ into the intrahepatic IVC ⇨ and the hepatic veins ↪. These are typical vascular imaging findings that are seen in congestive hepatopathy.* **(Right)** *Venoocclusive disease may occur after stem cell transplantation and may require TIPS creation to treat cirrhosis and portal hypertension. (A) Fluoroscopic and (B) DSA images show the classic "spider web" pattern ↪ of collaterals seen in venoocclusive disease.*

Lymphography

KEY FACTS

TERMINOLOGY

- **Conventional lymphography**
  - Historically used to assess lymph nodes/lymphatics
  - Supplanted by cross-sectional imaging
- **Thoracic duct**
  - Common drainage pathway of lymphatic system from abdomen, pelvis, lower extremities, left upper extremity
  - Drains into confluence of left subclavian/internal jugular veins
  - Common iliac lymphatics join to form paraaortic and paracaval lymphatic chains
  - Chains join, form cisterna chyli and thoracic duct

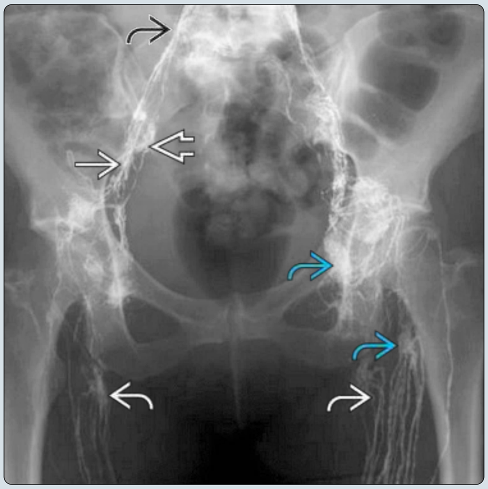
PREPROCEDURE

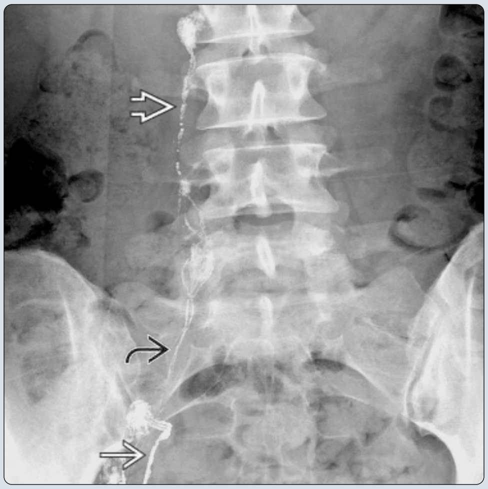
- Procedure indications
  - Characterize lymphatic fistulas, leaks
  - Visualize cisterna chyli
  - Facilitate percutaneous thoracic duct embolization
- Cross-sectional imaging (MR/CT) complementary modalities to assess lymphatic/lymph node pathology

PROCEDURE

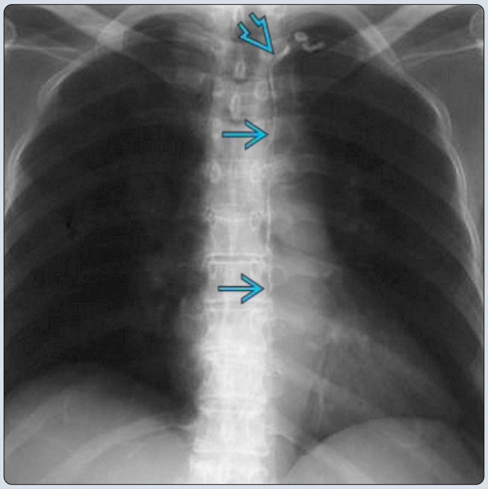
- Pedal injection
  - Inject Methylene blue in toe web spaces
  - Visualize lymphatics as blue streaks beneath skin
  - Perform cutdown over lymphatic vessel
    - Isolate lymphatic from surrounding fat
  - Cannulate lymphatic vessel with 30-g lymphography catheter
- Nodal Injection
  - US guidance
  - Puncture groin lymph node with spinal needle
- Infuse Ethiodol
  - Excellent opacification of lymph vessels, nodes
- Obtain serial spot images
- Monitor opacification of lymphatic system

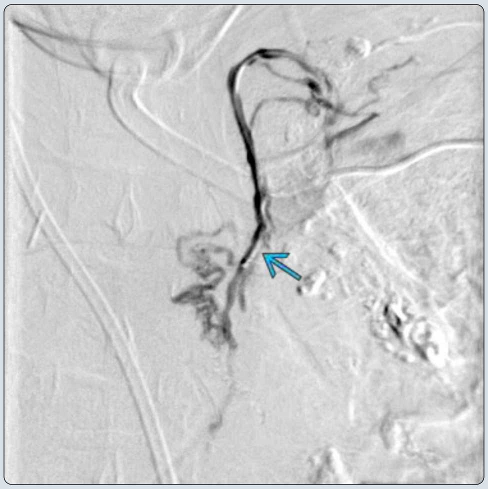
(Left) *Radiograph obtained during lymphography shows contrast in multiple lymphatic channels in both thighs ↪, as well as within the external →, internal ⇨, and common ↪ iliac lymphatics bilaterally. Nodal filling ↪ is also seen.* **(Right)** *Radiograph obtained several hours after lymphatic cannulation and Ethiodol infusion shows that the contrast is in the external → and common iliac ↪ lymphatic channels and also opacifies the paracaval lymphatics ⇨.*


Lymphangiogram: Pelvic


Lymphangiogram: Abdominal

(Left) *The thoracic duct ⇨ is seen in the left hemithorax, turning laterally ⇨ to join with the left brachiocephalic vein. The lymphatic fluid will then enter the venous system at the junction of the thoracic duct and left brachiocephalic vein.* **(Right)** *Successful canalization of thoracic duct has been achieved via a catheter advanced from left arm venous access. A microcatheter ⇨ has been advanced into the thoracic duct to the level of the mid chest. Injection shows multiple small collateral lymph channels in the chest.*


Lymphangiogram: Thoracic


Thoracic Duct (Direct Catheter Injection)

TERMINOLOGY

Definitions

- **Lymphography**: Radiopaque contrast injection into lymphatic vessel(s) to visualize lymphatic structures
  - Historically used to assess lymph nodes/lymphatics
  - Now infrequently performed
    - Supplanted by cross-sectional imaging
      - Imaging lymphatic system remains challenging
    - Invasive, time-consuming procedure
      - Lost art; technically difficult
- **Lymphangiography**: Synonym for lymphography
- **Lymphatic system**
  - Key component of immune system
    - Lymphocyte, plasma cell, mastocyte production
    - Transports immune cells
  - Includes structures involved in lymphocyte circulation/production: Bone marrow, lymphoid tissue of digestive system, lymphatic vessels, spleen, thymus
  - Involved in fluid transport/regulation in body
    - Absorbs intestinal fatty acids from lacteals
    - Transports chyle/lymph
      - Lymphatic contraction, 1-way valves promote flow through lymphatic system
    - Returns interstitial proteins to blood
  - Provides filtration of fluids through lymph nodes
- **Lymphatic anatomy**
  - Lymphatic capillaries in soft tissues
    - Coalesce to form lymphatic vessels
  - Lower extremity lymphatics combine in pelvis
    - Form internal and external iliac lymphatic chains
  - Common iliac lymphatics join to form paraaortic and paracaval lymphatic chains
    - Paraaortic and paracaval chains join to form cisterna chyli and thoracic duct
- **Cisterna chyli**
  - Fusiform, sac-like outpouching formed by confluence of lymphatic channels
  - Usually located along right posterior aspect of abdominal aorta
  - Variable location relative to vertebral level
    - T12-L2 level most frequently
  - May not be present
  - Caudal origin of thoracic duct
- **Thoracic duct**
  - Common drainage pathway of lymphatic system from abdomen, pelvis, lower extremities, left upper extremity
  - Carries 2-4 L of lymph daily
    - Proteins, lipids, lymphocytes
  - Originates at cisterna chyli
  - Courses superiorly in thoracic cavity
    - Extends from cisterna chyli level to base of neck
    - Right of midline; crosses to left at T5-6
    - Posterior to esophagus
    - Drains into confluence of left subclavian/IJ vein
  - May have multiple channels, variations, duplication

PREPROCEDURE

Indications

- Characterize lymphatic fistulas, diagnose and treat leaks
  - Chylous ascites or effusion
  - Chyluria
  - External genital lymphedema
  - Lymphocele
  - Presurgical planning
  - Confirm postoperative injury
- Neoplasm staging (rarely used for this indication)
  - Lymphoma
  - Metastatic disease
- Visualization of cisterna chyli/thoracic duct
  - Facilitate percutaneous thoracic duct embolization

Contraindications

- Allergy to Methylene blue, Lymphazurin, Ethiodol
- Pulmonary insufficiency
  - Some Ethiodol embolizes to lungs
- Right-to-left shunt
  - Ethiodol oil embolization to systemic circulation

Preprocedure Imaging

- Cross-sectional imaging (MR, CT)
  - Complementary modalities to assess pathology of lymphatic system and lymph nodes

Getting Started

- Medications
  - Conscious sedation medications
  - Lidocaine 1% subcutaneous injection
  - Blue dye for opacification of lymphatics; not needed for nodal puncture
    - Injected into web spaces between toes; taken up by lymphatics
      - Methylene blue (American Regent; Shirley, NY)
      - Isosulfan blue (Lymphazurin; Covidien; Mansfield, MA)
  - Lipiodol (Ethiodol; Guerbet; Villepinte, France)
    - Radiopaque contrast agent used for lymphography
    - a.k.a. ethiodized oil
      - Composition: Iodine (37%) combined with ethyl esters of fatty acids of poppyseed oil
  - Hurricaine spray (Beutlich; Waukegan, IL); not needed for nodal puncture
- Equipment list
  - Pedal
    - 30-g lymphography catheter (Cook Medical; Bloomington, IN)
    - Cutdown tray
    - 0-silk ties & 3-0 Prolene sutures
    - Slow infusion syringe pump/power injector
  - Nodal
    - Ultrasound, linear vascular probe
    - 25-g spinal needle, 7-cm length
    - Syringe pump; balloon insufflator may be used

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Pedal lymphography
    - Cisterna chyli usually on right side of upper abdomen
      - More effectively opacified from right foot
      - Left can be used if necessary
    - Patient supine, feet dangled over edge of table
      - Make patient comfortable: Procedure is lengthy, take care to prevent dislodgement of catheter
  - Nodal lymphography
    - Supine, prepare both groins for puncture

Procedure Steps

- **Pedal**
  - Sterilely prepare/drape feet
  - Administer topical anesthetic
    - Spray toe webspace prior to needle insertion
  - Inject methylene blue/Lymphazurin dye
    - Subcutaneous tissues of toe webspace, between 1st/2nd toes, 3rd/4th toes
    - Allow uptake into lymphatics
    - Blue streaks appear under skin within 7-10 minutes
  - Perform cutdown on dorsum of foot
    - Use 1% lidocaine for local anesthesia
    - Make a 2 cm longitudinal incision parallel to underlying lymphatic
  - Cannulate lymphatic vessel with 30-g catheter
    - Technically challenging, with small delicate lymphatics that are canalized
    - Secure needle within vessel with silk tie
    - Test for leak by injecting catheter/needle with small amount of saline
  - Secure lymphography catheter tubing
    - Minimize catheter dislodgement during infusion
    - Connect catheter to infusion pump
  - Infuse Ethiodol using pump
    - Provides excellent opacification of lymphatics/nodes
    - Does not dissolve through vessel walls; may remain in nodes for months/years
    - Can be used to treat slow leaks by itself
    - Use infusion rate of 8-12 mL/hour
    - Total infusion volume < 20 cc
    - Ensure that needle is not in vein
  - Monitor opacification of lymphatic system
    - Image every 15-20 minutes
    - Obtain serial fluoroscopic images, move from lower extremities to pelvis, to abdomen
    - Identify cisterna chyli
    - Identify thoracic duct
    - Total time 2-5 hours
  - Close wound
    - Use 3-0 Prolene, interrupted simple
    - Apply bacitracin and sterile dressing
  - Images can be repeated at 12/24 hours
    - CT or radiograph can be obtained
- **Nodal**
  - Sterile preparation of both groins
  - Use US guidance with linear vascular probe
    - Use lidocaine 1% subcutaneous
    - Access node with 25-g spinal needle, with tip at medulla/cortex border
    - Make only 1 pass into node if possible
  - Attach hub of needle to balloon insufflator filled with Ethiodol
  - Inject Ethiodol via needle using insufflator
    - Maintain insufflator at 2 mm Hg
    - Check insufflator every 5-10 minutes
  - Imaging same as pedal lymphography
  - As compared to pedal lymphography, nodal lymphography
    - Takes less time
    - Much smaller puncture site, no need for wound care
    - Increased technical success

Alternative Procedures/Therapies

- Radiologic
  - Nuclear lymphangioscintigraphy
  - Magnetic resonance lymphography
    - Interstitial injection of gadolinium
      - Followed by heavily T2-weighted imaging
    - Ultrasmall superparamagnetic iron oxide (USPIO) nanoparticles under investigation as MR contrast agent for imaging lymphatics
  - CT used for nodal assessment
    - Assessment limited to nodal enlargement
    - Does not image lymphatic vessels

POST PROCEDURE

Things to Do

- Carefully monitor Ethiodol infusion
  - If needle dislodges, pump continues infusing
    - Oily contrast evident in cutdown/on foot dorsum
  - Confirm that lymphatics continue to opacify with Ethiodol contrast
  - Confirm that needle is not in veins
- Wound care of pedal cutdown site
  - Suture removal at 10-12 days

OUTCOMES

Complications

- Immediate/periprocedural complication(s)
  - Pulmonary oil embolization, usually asymptomatic
    - Can have respiratory symptoms if underlying cardiopulmonary disorder
    - Minimize Ethiodol volume (e.g., ≤ 20 mL total)
  - Pulmonary infarction; chemical pneumonitis
  - Stroke
- Delayed complication(s)
  - Possible permanent skin discoloration from Methylene blue injection (pedal injection only)

Expected Outcome

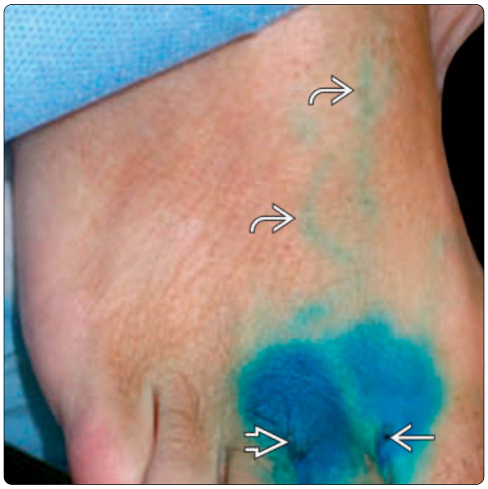
- Typically high technical success rates with experienced operators, more so with nodal lymphography

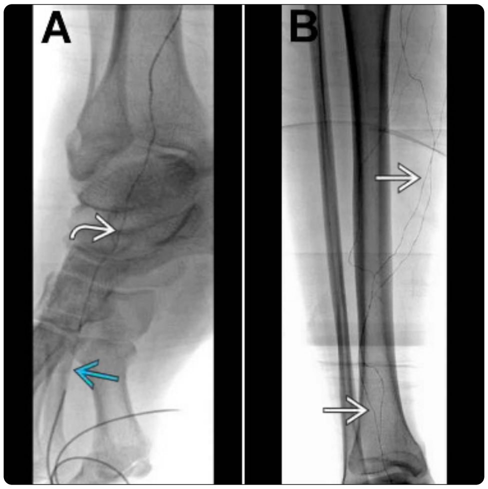
SELECTED REFERENCES

1. Sheybani A et al: Cerebral embolization of ethiodized oil following intranodal lymphangiography. Semin Intervent Radiol. 32(1):10-3, 2015

Step-by-Step: Lymphography (Methylene Blue Injection)

Step-by-Step: Lymphography (Lymphatic Cannulation)

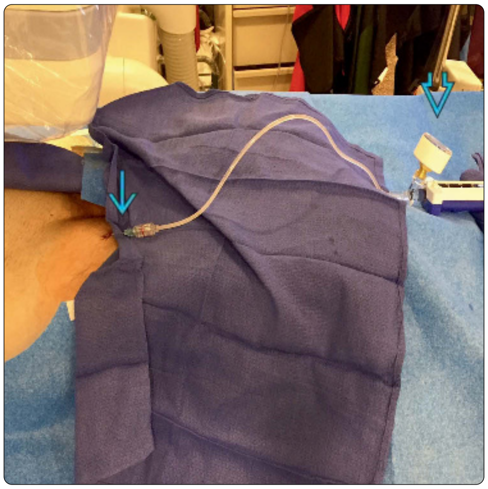


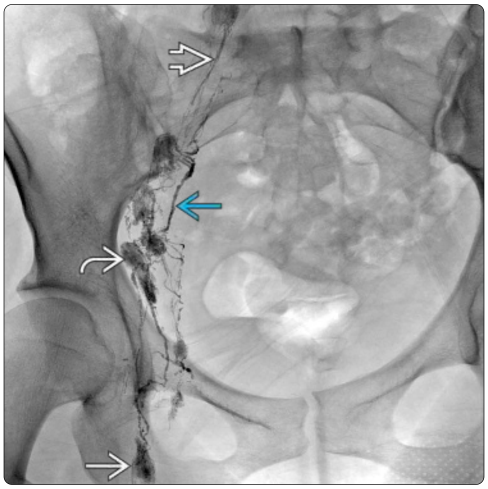


(Left) *Methylene blue is injected in the web spaces between the great and 2nd toes ➡ and between the 2nd and 3rd toes ➡. The dye accumulates in the lymphatics ↪ just deep to the skin, which are then accessed with a 30-g needle.* **(Right)** *(A) A lymphatic on the dorsum of the right foot has been cannulated with a 30-g needle ⇨ and Ethiodol has been injected, opacifying the dorsal lymphatic ↪. (B) Ethiodol opacifies multiple lymphatic channels ➡ in the lower leg.*

Step-by-Step: Lymphography (Intranodal Access Setup)

Step-by-Step: Lymphography (Fluoroscopic Monitoring at Pelvis)

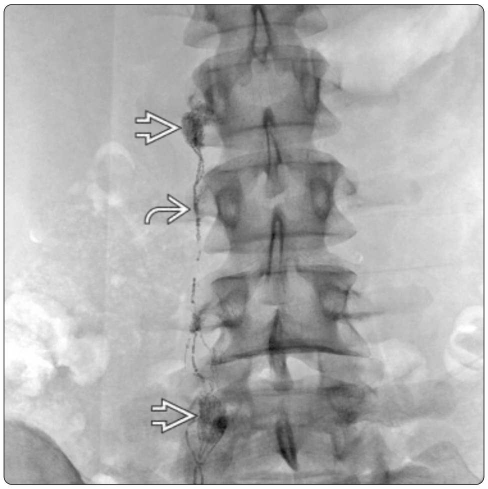


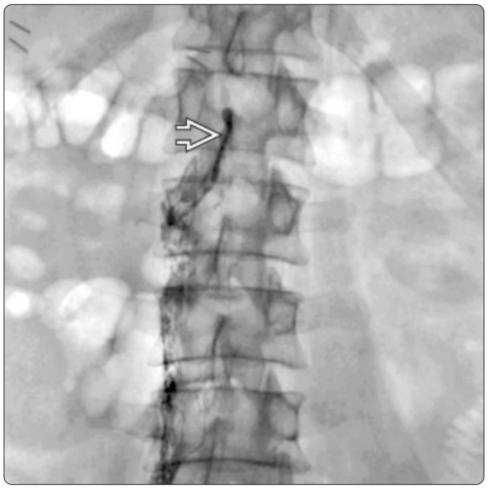


(Left) *Rather than pedal access, nodal access can be achieved. A 25-g 7-cm spinal needle ⇨ is used to access the lymph node. The needle is then attached to an insufflator ⇨ filled with Ethiodol, which is injected at 2 mm Hg.* **(Right)** *Fluoroscopic monitoring of contrast ascent should be periodically performed during the procedure, particularly when assessing for a lymphatic leak. Here, contrast fills the right external iliac ⇨ and common iliac ➡ lymphatic channels, plus inguinal ➡ and external iliac ↪ lymph nodes.*

Step-by-Step: Lymphography (Fluoroscopic Monitoring at Abdomen)

Step-by-Step: Lymphography (Identification of Cisterna Chyli)





(Left) *Ethiodol contrast opacifies the right paracaval lymphatics ↪ including paracaval lymph nodes ➡.* **(Right)** *Contrast opacifies the cisterna chyli ➡. This sac-like dilatation is formed by the confluence of the paralumbar (paraaortic/paracaval) lymphatics, which are joined by lymphatics that drain the intestinal tract. The thoracic duct continues from the cephalad end of the cisterna chyli and initially courses to the right of midline before ascending in the posterior mediastinum.*

Thoracic Duct Embolization

KEY FACTS

TERMINOLOGY

- Thoracic duct embolization
  - 2-phase procedure
    - Conventional pedal lymphography or intranodal lymphography: Visualize cisterna chyli or dominant upper lumbar lymphatic
    - Cannulation, embolization of thoracic duct
- Relatively underutilized procedure
  - Recommended 1st-line therapy for postoperative chylothorax failing conservative management

PREPROCEDURE

- Indications
  - Thoracic duct injury
  - Malignant thoracic duct disruption
  - High-volume chylous pleural effusion
  - Failed conservative therapy
- Alternative to open surgical thoracic duct ligation

PROCEDURE

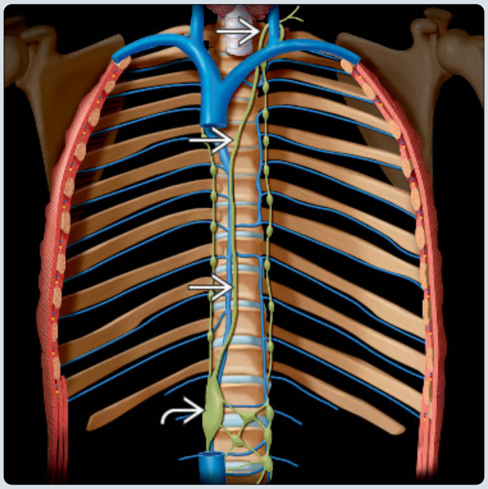
- Perform pedal or intranodal lymphography; visualize lymphatics
- Access cisterna chyli or target lymphatic channel
  - Percutaneous transabdominal approach
  - Use 22-gauge needle
  - Technically challenging
- Introduce 0.018" guidewire into duct
- Advance microcatheter into thoracic duct
- Embolize thoracic duct/leak
  - Use small-diameter coils and liquid embolics
- If thoracic duct is not successfully cannulated
  - Make multiple needle passes; disrupt, macerate cisterna chyli/lymphatics

OUTCOMES

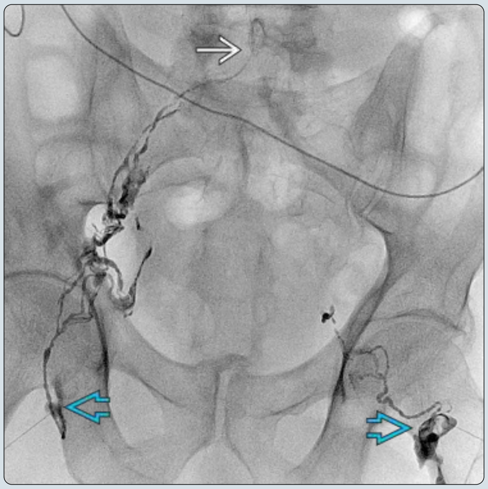
- 50-70% clinical success rate

(Left) *Graphic shows the cisterna chyli* ↪*, a sac-like dilatation formed by the confluence of the paracaval and paraaortic lymphatics. The thoracic duct* ➡ *arises from the cisterna chyli and ascends to the base of the neck.* **(Right)** *After US-guided bilateral lymph node puncture* ⇨*, Ethiodol is being infused into the lymphatics. The leading edge of the Ethiodol* ➡ *is now in the upper pelvis.*

Lymphatic System: Upper Abdomen & Chest

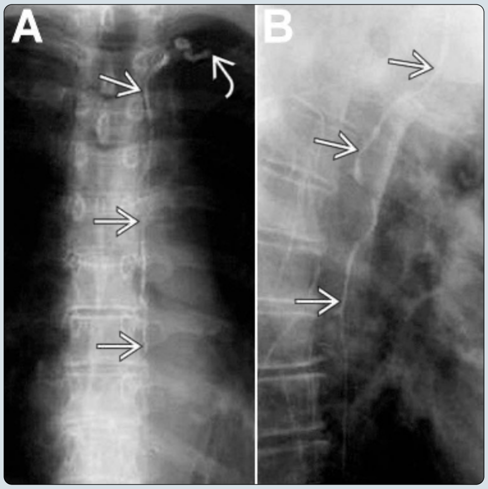


Bilateral Groin Lymphangiogram

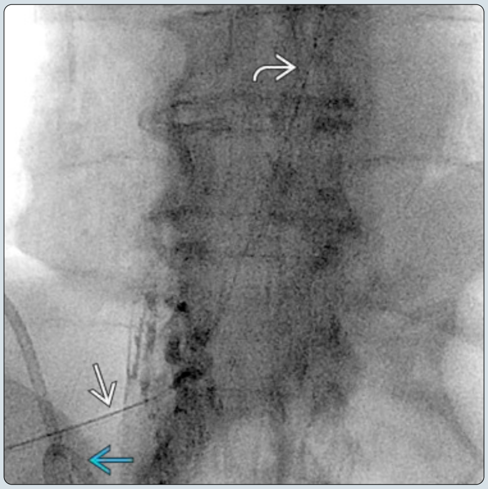


(Left) *Postlymphography (A) frontal and (B) lateral images show that, within the chest, the thoracic duct* ➡ *courses posteriorly on the left. Its terminal end* ↪ *drains into the left subclavian vein at the internal jugular vein confluence.* **(Right)** *Imaging shows a 22-gauge needle* ➡ *used to puncture the thoracic duct. An wire (0.018")* ↪ *was advanced into the thoracic duct. The patient has a right-sided chest drain* ⇨ *draining a chylous pleural effusion.*

Lymphangiogram in Upper Chest



Percutaneous Puncture of Thoracic Duct



TERMINOLOGY

Definitions

- **Thoracic duct embolization**
  - 2-phase procedure
    - Conventional pedal lymphography or intranodal lymphography
      - Visualize cisterna chyli or dominant upper lumbar lymphatics
    - Cannulation, embolization of thoracic duct
      - Percutaneous anterior abdominal approach
  - 2 types of treatment described
    - Type 1 thoracic duct embolization
      - Direct thoracic duct cannulation, embolization
    - Type 2 thoracic duct embolization
      - Cisterna chyli maceration
      - Disruption of duct
      - Diverts chyle flow into retroperitoneum
      - Promotes healing of breach
  - Relatively underutilized procedure
    - Lack of physician awareness
    - Lack of technical familiarity with procedure
    - Low morbidity, mortality
    - Recommended 1st-line therapy for persistent postoperative chylothorax
      - Surgery has higher primary success rate but higher mortality
- **Cisterna chyli**: Dilated lower end of thoracic duct
  - Formed by confluence of intestinal trunk/lumbar lymphatic trunks
    - Receives fatty chyle from intestines
    - Acts as conduit for lipid digestive products
  - Located between L2 and T12 levels
- **Thoracic duct**
  - Largest lymphatic vessel in body
    - Typically 38-45 cm in length, 5 mm in diameter
    - Extends to base of neck
    - Arises from cephalad end of cisterna chyli
      - Ascends posterior mediastinum between descending aorta/azygos vein
      - Posterior to esophagus; slightly right of midline
      - Crosses to left of midline at T5-T6
    - Terminates at left subclavian/internal jugular vein confluence where it empties into venous system
  - Transports up to 4 L of lymph/day
    - Valves prevent retrograde lymph flow
    - Valves at duct junction with left subclavian vein
      - Prevents venous blood flow into thoracic duct
  - 10% incidence of duplicated (bilateral) thoracic duct
  - Causes of thoracic duct injury
    - Surgery: Pulmonary or esophageal
    - Trauma: Penetrating thoracic
    - Malignancy: Lymphoma, lymphadenopathy/metastasis
- **Chylous effusion (chylothorax)**
  - Complication of thoracic/cardiac/neck surgery
    - Rare complication; significant morbidity/mortality
      - Thoracic surgery procedures: 0.4-2.0% incidence
      - Post esophagectomy: Up to 3.9%
    - Milky appearance; chylomicrons
      - Triglyceride level above 110 mg/dL
  - Low-output chylothorax (< 1,000 mL/day) treated conservatively
    - Total parental nutrition
    - Medium-chain fatty acid diet
  - High-output chylothorax (> 1,000 mL/day) mandates intervention; has high mortality rate
    - 50% mortality with conservative treatment
    - May have ≥ 10-15% mortality with surgical repair in high-risk patients
    - Chyle rich in nutrients/T cells/electrolytes
      - Consists mainly of lymph/fat digestion products
      - Prolonged leakage worsens patient condition

PREPROCEDURE

Indications

- High-volume chylothorax (> 1,000 mL/day)
  - Persistent lymph loss
    - High mortality due to electrolyte imbalance, dehydration, immune compromise, respiratory distress, nutritional depletion
  - Failure of conservative therapy
    - Conservative therapy includes limiting oral intake, limiting fat intake, using total parenteral nutrition, draining pleural fluid via chest tube placement
    - ~ 1/4 will resolve
      - Smaller leaks (< 500 mL/day)
      - > 500 mL/day usually unresponsive to conservative management
    - May take 2-3 weeks
  - Increasing output despite conservative therapy
- Alternative to open surgical thoracic duct ligation
  - Increased mortality, complications

Contraindications

- Pseudochylous effusions
  - Cholesterol-dominant lipid component
  - Triglyceride level below 50 mg/dL
  - Absent chylomicrons
  - Caused by tuberculosis and rheumatoid disease
  - Not caused by thoracic duct disruption
- Chylothorax responsive to conservative management
- Low ligation of thoracic duct
- Uncorrectable coagulopathy/bleeding diathesis
- Contraindication to lymphography

Getting Started

- Things to check
  - Pertinent clinical history and physical evaluation
    - Etiology of chylothorax
      - Prior management and response
    - Procedure indications; any contraindications, especially to Ethiodol
  - Review cross-sectional imaging
  - Allergies
  - Pertinent laboratory parameters
    - Complete blood count
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ratio ≤ 1.7

  - Written informed procedural consent
- Medications
  - Broad spectrum antibiotics
    - May traverse bowel, liver, pancreas during thoracic duct cannulation
- Equipment list
  - Equipment used for lymphography
  - 22-gauge Chiba needle, 15 or 20 cm in length (dependent on patient size)
  - V-18 guidewire (Boston Scientific; Natick, MA)
  - 3-Fr x 80-cm Slip-Cath infusion catheter (Cook Medical; Bloomington, IN) or 2.7-Fr microcatheter
  - Embolization coils
  - Trufill (n-butyl cyanoacrylate) liquid embolic system (Cordis; Bridgewater, NJ); Onyx (ev3, Plymouth, MN) liquid embolic can be substituted

PROCEDURE

Procedure Steps

- Perform lymphography
  - Visualize cisterna chyli/target lymphatic for cannulation
    - If poor visualization at lymphography
      - Consider saline bolus via cannulated lymphatic
      - Propel intralymphatic contrast to cisterna chyli
- Sterilely prepare/drape upper abdomen
- Access cisterna chyli or target lymphatic channel
  - 22-gauge needle, fluoroscopic guided
  - Right paramedian percutaneous approach
    - Avoid aorta
  - Technically challenging
    - Small structure
    - Requires accessing deep retroperitoneum
  - Negotiate 0.018" guidewire into duct
  - Advance catheter over wire
- Digital subtraction lymphography of thoracic duct
  - Confirm placement within duct
  - Assess/localize leak
- Insert stiff 0.018" guidewire (e.g., V-18)
- Catheter placement over wire
  - Advance to level of leak
  - Repeat digital subtraction lymphography
  - Characterize leak
- Embolize thoracic duct and leak
  - Position microcatheter as close as possible to leak
    - Optimally bridge point of extravasation
  - Introduce small embolization coils via microcatheter
    - Use 4- to 6-mm diameter coils
  - Embolize entire length of thoracic duct
    - Terminate embolization within 2 cm of entry site
- Liquid embolic injection
  - Seal lower thoracic duct and needle entry site
  - Remove catheter while aspirating
    - Minimize extravasation
- Final spot radiographs
  - Chest, abdomen
  - Document position of embolic implants
- If thoracic duct is not successfully cannulated
  - Perform type 2 thoracic duct embolization
  - Disrupt, macerate cisterna chyli and lymphatics
    - Perform serial needle passes with 22-gauge needle
      - Diverts chyle into retroperitoneum; allows healing of thoracic duct injury in chest

Alternative Procedures/Therapies

- Radiologic
  - Retrograde thoracic duct cannulation/embolization
    - Alternative approach to direct percutaneous thoracic duct cannulation/embolization
      - Used when traditional approach unsuccessful
      - Requires lymphographic demonstration of thoracic duct entry to left subclavian vein
    - Brachial vein access with sheath
    - Angled catheter positioned in left subclavian vein
    - Coaxial microcatheter/microwire used to cannulate thoracic duct ostium
      - Advanced into duct
      - Microcatheter/wire advanced to cisterna chyli
    - Contrast ductography at multiple levels
    - Embolization through microcatheter
      - Coils/liquid embolic/Gelfoam slurry
- Surgical
  - Surgical exploration
    - Thoracic duct ligation
      - 90-92% success rate
    - Higher morbidity than percutaneous embolization
      - 38-43% complication rate
      - 2% mortality rate

POST PROCEDURE

Things to Do

- Monitor pleural fluid output
- Continue dietary restriction
  - Advance diet if chylothorax resolving/chest tube output < 500 mL/day
    - Repeat restrictions if diet increases chyle output

OUTCOMES

Problems

- Inability to identify, cannulate cisterna chyli or appropriate lymphatic vessel to perform embolization

Complications

- Immediate/periprocedural complication(s)
  - Complications of lymphography
  - Nontarget embolization

Expected Outcomes

- Chylous effusion output diminishes over several days
- 50-70% reported clinical success rate
  - In 1 series (42 patients)
    - Overall 69% cure and partial response rate
      - Type 1 embolization: 85% success rate
      - Type 2 embolization: 45% success rate

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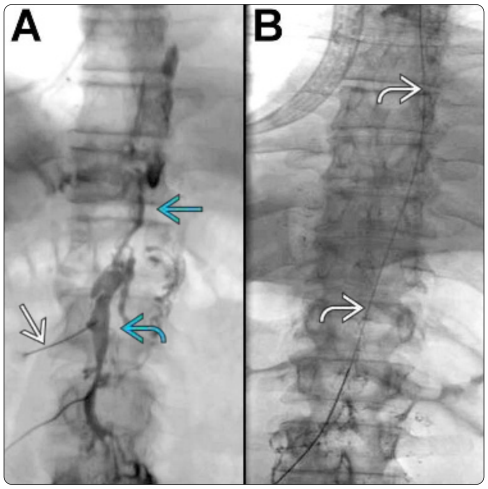
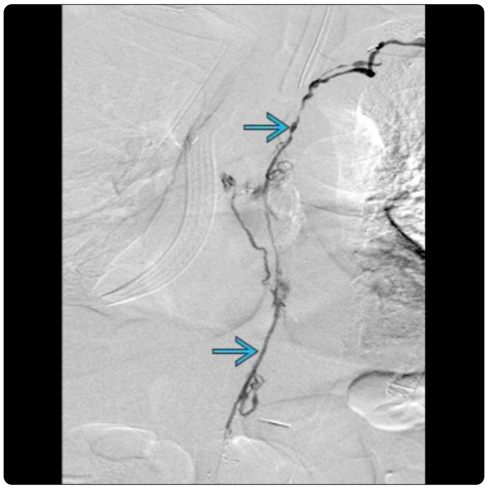
1. Nadolski G: Nontraumatic chylothorax: diagnostic algorithm and treatment options. Tech Vasc Interv Radiol. 19(4):286-290, 2016
2. Gaba RC et al: Chylous ascites: a rare complication of thoracic duct embolization for chylothorax. Cardiovasc Intervent Radiol. 34 Suppl 2:S245-9, 2011

Thoracic Duct Embolization: Initial Cannulation of Duct

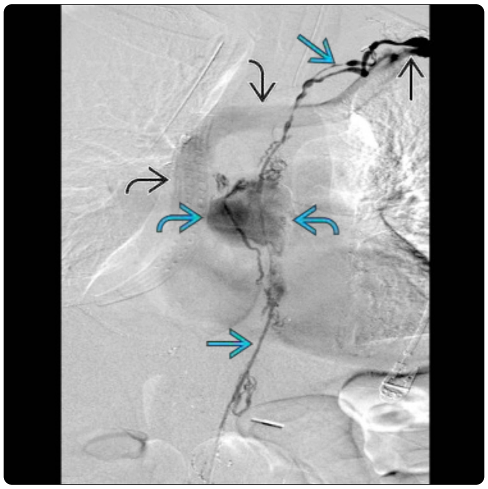


Thoracic Duct Embolization: Inner Catheter Advancement (DSA Thoracic Ductography)

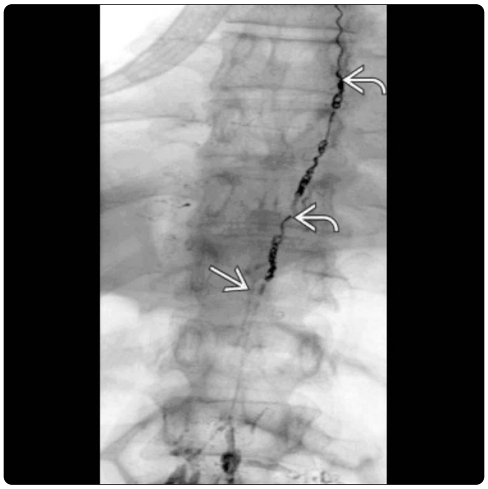


(Left) *Spot radiographs show that (A) a 21-gauge needle* ➡ *has been successfully introduced to cisterna chyli* ↪ *at the base of the thoracic duct* ⇨*. Ethiodol contrast has been injected. (B) After needle placement, a 0.018" guidewire* ↪ *is advanced into the thoracic duct within the chest.* **(Right)** *After guidewire placement, a trocar and 3-Fr inner catheter are advanced over the guidewire into the thoracic duct. DSA lymphography of the thoracic duct* ⇨ *is then performed to confirm ductal cannulation and localize the chyle leak.*

Thoracic Duct Embolization: Localization of Chyle Leak

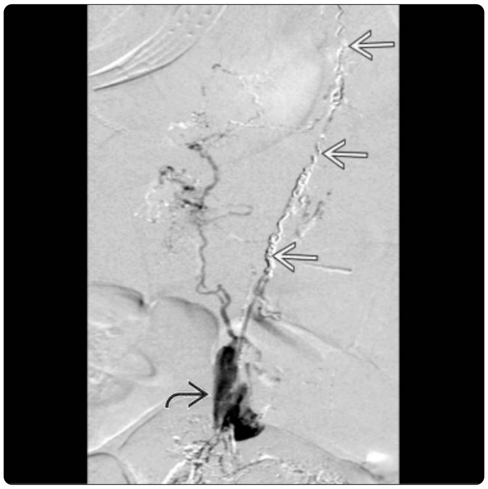


Thoracic Duct Embolization: Coil Embolization

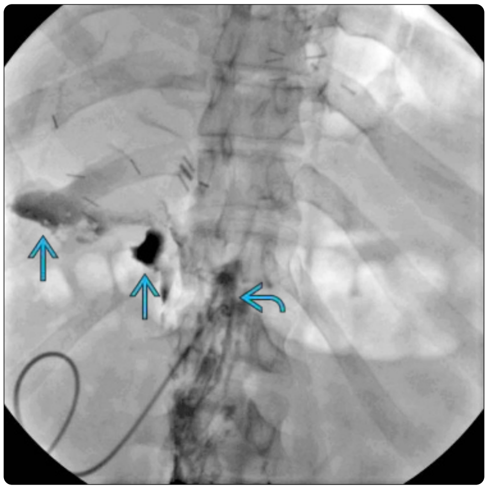


(Left) *DSA lymphography shows the course of the thoracic duct* ⇨ *and where it drains into the left subclavian vein* ⇨*. Contrast from the thoracic duct opacifies the venous system* ↪ *but also leaks* ↪ *into the pleural space.* **(Right)** *Fluoroscopic spot radiograph obtained following transcatheter thoracic duct embolization with multiple small (4- to 6-mm diameter) coils* ↪ *shows that the entire length of the duct was embolized within the chest to within 2 cm of the point of needle access* ➡*.*

Thoracic Duct Embolization: Embolization With Coils and Glue



Thoracic Duct Embolization: Needle Maceration of Cisterna Chyli



(Left) *Multiple embolization coils* ➡ *were placed along the duct; the leak is no longer present. The lower duct and needle entry into the cisterna chyli were sealed with Trufill (n-butyl cyanoacrylate)* ↪*.* **(Right)** *If the cisterna chyli is visualized but cannot be successfully cannulated for embolization, multiple needle passes can be used to macerate the cisterna chyli* ↪*. This diverts chyle flow into retroperitoneum, as shown by the extravasation* ⇨*, thereby allowing healing of the leak in the thorax.*

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SECTION 3

Arterial Procedures

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Arterial Access

KEY FACTS

TERMINOLOGY

- **Common femoral artery access**
  - Most frequent access, usually retrograde
- **Radial artery access**
  - Alternative to common femoral access
    - Consider in cases of iliac occlusion or steep caudal angulation of target visceral arteries
  - Faster discharge, increased patient satisfaction
- **Brachial artery access**
  - Higher complication rate than femoral route
  - Fewer complications with low brachial artery access vs. high brachial/axillary access
- **Aortic access**
  - Direct needle puncture of abdominal aorta
- **Tibiopedal**
  - Treatment of chronic limb ischemia; limb salvage
  - Retrograde access to recanalize infrapopliteal occlusions

PROCEDURE

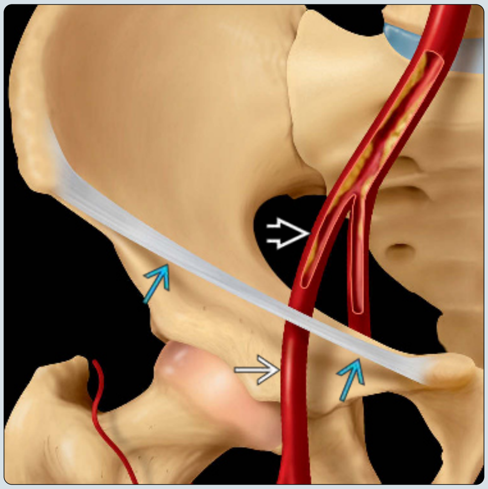
- **Femoral artery puncture**
  - Access over femoral head
  - Confirm access point via fluoroscopy or US
- **Radial artery puncture**
  - Perform Barbeau test
    - Type D waveform is absolute contraindication
  - 30 min prior to access, administer topical lidocaine & nitroglycerin to dilate radial artery
  - Slowly inject solution of nitroglycerin, heparin, & calcium channel blocker through sheath

POST PROCEDURE

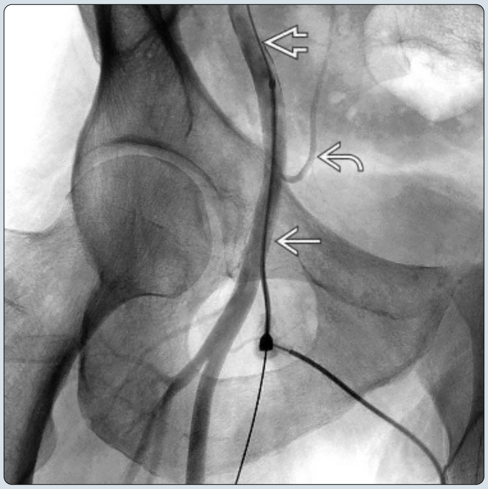
- **Femoral artery hemostasis**
  - Manual compression for 15 min
  - Closure device: Earlier ambulation & discharge than manual compression
- **Radial artery hemostasis**
  - Inflatable wrist band decreases thrombosis risk

(Left) *The inguinal ligament* → *anatomically delineates the boundaries of the external iliac* ⇨ *& common femoral* → *arteries. Inadvertent arterial access superior to the inguinal ligament can lead to intraabdominal bleeding.* **(Right)** *Arteriogram through a common femoral artery access sheath confirms that percutaneous access was properly achieved overlying the femoral head. Access is inferior to the inferior epigastric artery* ↪*, marking the inguinal ligament bordering common femoral* → *& external iliac arteries* ⇨*.*

Inguinal Ligament

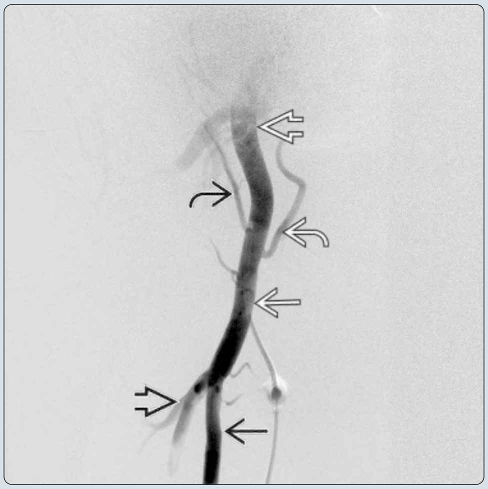


Femoral Artery Access (Native)

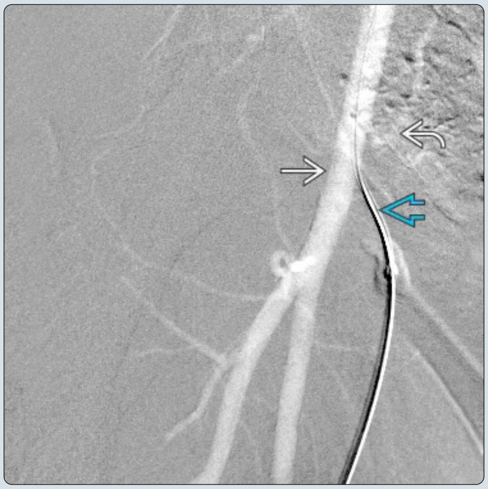


(Left) *DSA again demonstrates the common femoral* →*, external iliac* ⇨*, & inferior epigastric* ↪ *arteries. In addition to the superficial* → *& deep femoral* ⇨ *arteries, the deep circumflex iliac* ↪ *artery is seen.* **(Right)** *CO_2 contrast was used to evaluate access in this patient with acute renal insufficiency. The femoral sheath* ⇨ *accesses the common femoral artery* →*. The inferior epigastric artery* ↪ *is seen marking the inguinal ligament.*

Femoral Artery Access (DSA)



Femoral Artery Access (DSA With CO_2)



TERMINOLOGY

Definitions

- **Arterial access**: Needle puncture, guidewire, & subsequent sheath/catheter introduction, providing arterial access for angiography/vascular intervention
  - **Common femoral artery (CFA) access**
    - Most frequent access site
    - Majority of punctures retrograde
  - **Radial artery access**
    - Alternative to CFA access primarily utilized with coronary interventions, less common for subdiaphragmatic interventions
    - Transradial access (TRA) vs. CFA
      - ☐ Overall complication rate & safety ≤ CFA access
      - ☐ Reduced complications in obese patients
      - ☐ Increased patient satisfaction (quality of life)
    - No closure devices necessary: Reduced procedural cost, no foreign body deployed
    - Requires preprocedure Barbeau test
  - **Brachial artery access**
    - Alternative to CFA or radial access for anticipated upper extremity intervention or improved route when engaging caudally directed visceral arteries
    - Low brachial artery access preferred vs. high access
    - Axillary artery access has higher complication rate than femoral or radial access
      - ☐ Hematoma may track within medial brachial fascial compartment & compress brachial plexus
      - ☐ High brachial artery access risks similar to axillary
  - **Popliteal**
    - Nontraditional access, usually for intervention [e.g., superficial femoral artery (SFA), distal infrapopliteal arteries]
  - **Tibiopedal**
    - Treatment of chronic limb ischemia; limb salvage
    - Retrograde access; typically following failed antegrade recanalization of infrapopliteal occlusions in ischemic angiosome
  - **Aortic access**
    - Direct needle puncture of abdominal aorta with subsequent sheath/catheter placement
      - ☐ Selective arterial catheterization difficult
      - ☐ Often used for translumbar endoleak repair

PREPROCEDURE

Indications

- Provide arterial route for sheath/catheter introduction
  - Diagnostic arteriography
  - Endovascular arterial intervention

Contraindications

- **Absolute contraindications**
  - General: Presence of pseudoaneurysm, hematoma, or active infection in area of target vessel
  - Radial artery access: Type D waveform during Barbeau test; occlusion of radial artery or ulnopalmar arch
  - Aortic access
    - Inability of patient to lie prone; severe scoliosis
    - Dense circumferential aortic calcification
- **Relative contraindications**
  - Coagulopathy
    - Prefer international normalized ratio (INR) ≤ 1.5, platelet count ≥ 50,000/μL
    - No consensus on activated partial thromboplastin time, many correct if ≥ 1.5x control
    - Consider withholding 1 dose (12 hours) of low-molecular-weight heparin
    - Consider withholding clopidogrel 5 days; no need to withhold aspirin
  - Uncontrolled hypertension
  - Recent vascular surgery near access site
  - Heavy calcification of target artery
  - Radial/brachial/axillary artery access
    - Proximal arterial stenosis/occlusion
    - Significant aortic tortuosity
    - Limited shoulder mobility
  - Radial artery access
    - Small radial artery < 2-mm diameter
    - Current or anticipated dialysis; preserve radial artery for potential fistula
    - Sheath size > 6-7 Fr

Preprocedure Imaging

- Exclude anatomic variants, central occlusions, or orientation of visceral/target arteries altering preference for access route
- Review anatomic layout/anastomoses of prior vascular bypass surgery

Getting Started

- Things to check
  - Clinical history & physical examination
    - Indications, appropriateness of procedure
    - Detailed pulse examination/Doppler evaluation
      - ☐ Perform Barbeau test prior to radial access
    - Current medications
      - ☐ Any anticoagulants, antiplatelet agents, oral hypoglycemic agents, antihypertensives
      - ☐ Stop heparin 2-4 hours prior to procedure
  - Allergies
    - Elective contrast allergy premedication (either of 2 corticosteroid options plus optional antihistamine)
      - ☐ Methylprednisolone (Medrol) 32 mg PO at 12 hours & 2 hours prior to injection
      - ☐ Prednisone 50 mg PO, 13 hours, 7 hours, & 1 hour prior to procedure
      - ☐ Diphenhydramine (Benadryl) 50 mg IV, IM, or PO at 1 hour prior may also be added to either corticosteroid
    - Emergency contrast allergy premedication (3 options)
      - ☐ Best option if feasible: Methylprednisolone sodium succinate (Solu-Medrol) 40 mg IV **or** hydrocortisone sodium succinate (Solu-Cortef) 200 mg IV every 4 hour until injection **&** diphenhydramine (Benadryl) 50 mg IV 1 hour prior to injection
      - ☐ 2nd best option if feasible: Dexamethasone sodium sulfate (Decadron) 7.5 mg IV **or** betamethasone 6 mg IV every 4 hours until injection **&** diphenhydramine (Benadryl) 50 mg IV 1 hour prior to injection

      - 3rd option if steroids cannot be given: Diphenhydramine (Benadryl) 50 mg IV 1 hour prior
  - Laboratory results
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
      - Vigorous hydration if renal dysfunction
      - Sodium bicarbonate drip if renal dysfunction
    - Complete blood count
      - Platelet count > 50,000/µL
    - Coagulation profile
      - INR ≤ 1.5
      - Normal prothrombin time, partial thromboplastin time
  - Limit oral intake: NPO for 8° prior to procedure
    - Necessary for moderate sedation
    - Take any oral medications with sip of water
  - Written informed procedural consent obtained
- Medications
  - Lidocaine for local anesthesia
    - 1 or 2% concentration
    - 10-mL syringe with 25-g needle
  - Moderate (conscious) sedation medications
    - Fentanyl/midazolam typically used
  - Small diameter artery access (e.g., radial, tibiopedal, brachial)
    - Vasodilators: Combination of 200 µg nitroglycerin, 2.5-5.0 mg of verapamil delivered via sheath
    - Systemic anticoagulation: 3,000-5,000 units heparin IV bolus, followed with 1,000 units heparin/hour, titrated to activated clotting time > 250
  - Prophylactic antibiotics: Procedure specific
    - Commonly 1 g IV cefazolin
      - If allergic to penicillins, can do vancomycin or 600-900 mg IV clindamycin
- Equipment list
  - Fluoroscopy equipment
  - US equipment (if US-guided access): 5- to 8-MHz probe, sterile probe cover & gel
  - Microaccess set: 21-g access needle, 0.018" guidewire, microaccess transitional dilator
  - Guidewire (e.g., 0.035" J-tip "starter" guidewire)
  - #11 blade scalpel

PROCEDURE

Patient Position/Location

- Best procedure approach
  - **Femoral artery access**: Patient supine, both lower extremities extended
  - **Radial artery access**: Patient supine, arm supinated, often adducted near patient's side
  - **Brachial artery access**: Patient supine, arm supinated, abducted 70-90° or adducted near patient's side
    - High brachial: Arm abducted/elbow extended
    - Axillary: Arm abducted, elbow flexed, head on hand
  - **Popliteal artery access**: Patient prone or steep oblique
  - **Tibiopedal**: Patient supine, typically performed concurrent with femoral artery access
  - **Aortic access**: Patient prone, typically left paraspinal access point

Procedure Steps

- General
  - Assess distal extremity pulses & document prior to attempting access
- **Femoral artery access**
  - Access site: Over medial femoral head
    - Avoid high puncture: Unable to compress, potential intraabdominal bleed
    - Avoid low puncture: Potential inadvertent SFA access; higher complication rate
    - CFA calcifications may serve as fluoroscopy target
  - Fluoroscopy-guided access
    - Palpate arterial pulse
    - Place radiopaque instrument (e.g., hemostat) over pulse at planned entry site
      - Retract any overlying pannus; reduces depth required for needle entry into artery
    - Fluoroscopically confirm instrument overlies planned access point of target artery
  - US-guided access: Observe needle entry to CFA
    - Scan planned access site to identify artery
    - Use probe to retract pannus
  - Anesthetize skin & deeper tissues with lidocaine
    - Skin entry point should be 1-2 cm below (retrograde access) or above (antegrade access) intended needle entry point into artery
  - Use #11 blade to make 5-mm skin nick
    - Spread skin/subcutaneous tissue with hemostat
  - Hold micropuncture needle in one hand
  - Place tips of index & middle fingers of other hand above & below skin nick, palpate pulse
    - Alternatively, target artery with US
  - Advance needle slowly through nick at 45° angle
    - When needle tip contacts artery, should feel transmitted pulsations
  - Pulsatile flow confirms access
  - Stabilize needle position
  - Introduce guidewire through needle hub
    - Use atraumatic guidewire, such as J-tip
    - Avoid hydrophilic wire (needle may strip wire)
  - If resistance to guidewire passage
    - Stop advancing wire immediately
    - Using fluoroscopy, gently redirect needle tip to align with vessel long axis; try wire again
    - Continued resistance: Remove needle & wire as unit
  - After successfully introducing guidewire, remove needle over wire, introduce sheath or catheter
  - Perform arteriogram to evaluate access
- **Radial artery access**
  - Access site: At wrist, 2 cm proximal to radial styloid
    - Left-sided access preferred, prevents catheter from traversing common carotid arteries
  - Perform Barbeau test (modified Allen test)
    - Place pulse oximeter on thumb (or 2nd digit), observe waveform
    - Compress radial artery for 2 min, continue to monitor waveform
      - Type A: No change of waveform
      - Type B: Damping of waveform
      - Type C: Loss of waveform, recovers within 2 min

      - Type D: Loss of waveform without recovery
      - A-C waveforms: Confirm ulnopalmar arch patency
      - D waveform: Contraindication to radial access
    - Leave pulse oximeter on thumb/2nd digit throughout case
  - Predilate protocol: Increases radial artery diameter
    - Topical application 30 min prior to access
    - Nitroglycerin ointment (30 mg) & lidocaine cream (40 mg); some substitute lidocaine with EMLA cream (lidocaine 2.5%, prilocaine 2.5%)
  - Hyperextend wrist (use towel roll to support wrist)
  - May access ± US guidance
    - No skin nick necessary
    - With US: Seldinger technique & 21-g needle; confirm needle tip within vessel
    - Without US: Palpate artery, advance Angiocath with double-wall technique, withdraw Angiocath until blood seen
  - Insert 0.018" guidewire
    - If resistance encountered, stop, visualize fluoroscopically
    - May inject contrast to confirm access
    - Consider using Nitrex 0.018" wire for difficult cases
  - Remove needle/Angiocath over wire
  - Insert hydrophilic radial sheath over guidewire
    - Skin nick or transitional sheath often unnecessary
    - Can typically use as large as 6- to 7-Fr sheath
    - Several radial-specific sheaths exist with 6-Fr inner lumen but 5-Fr outer diameter (e.g., Glidesheath Slender; Terumo)
      - Thin wall; access other than radial may kink sheath
  - Inject combination of nitroglycerin (200 μg), heparin (3,000 units), & calcium channel blocker (2.5 mg of verapamil) through sheath
    - Reduces risk of vasospasm &/or occlusion
    - Verapamil injection burns: Inject slowly & hemodilute
  - Perform arteriogram to evaluate access
- **Brachial (low) artery access**
  - Access site: Several centimeters proximal to antecubital fossa
    - Left arm access preferred: Direct course to descending thoracic aorta, most patients right-handed
    - Right arm access: Consider if left subclavian disease or patient left-handed
  - Consider US guidance during access to optimize result, minimize complications
    - Confirm location of artery; avoid adjacent nerves
  - Anesthetize skin with lidocaine
    - Little deep anesthesia; avoids inadvertent nerve block (mimics hematoma compressing nerve)
  - Advance micropuncture needle through skin at 45° angle; confirm tip location with US
    - Advance needle tip to contact arterial wall
    - Advance needle into arterial lumen
  - Confirm pulsatile blood return from needle hub; stabilize needle position
  - Introduce 0.018" guidewire through needle hub
  - Remove needle over wire, introduce microaccess sheath
  - Remove wire/dilator from microaccess sheath
  - Introduce 0.035" guidewire (prefer J-tip)
  - Advance sheath; utilize lowest profile reasonable
  - Perform arteriogram to evaluate access
  - Deliver systemic anticoagulation (e.g., heparin)
  - Consider delivering vasodilators via sheath (nitroglycerin, verapamil) for small-caliber artery, prone to vasospasm
- **Popliteal artery access**
  - Access site: Puncture artery in popliteal fossa
    - Identify popliteal artery & vein with US
      - Vein superficial (posterior) to artery
    - Anesthetize skin with lidocaine
    - Access with US/micropuncture set, avoid vein
    - Confirm pulsatile blood return from needle hub
    - Introduce 0.018" guidewire through needle hub
    - Remove needle, introduce transitional sheath, advance 0.035" wire
    - Replace transitional with small standard sheath
- **Tibiopedal artery access**
  - Access site: Dependent on angiosome location
    - Anterior tibial: Proximal to tibiotalar (ankle) joint
    - Dorsalis pedis: Just proximal to navicular bone
    - Posterior tibial: Overlying medial malleolus, may be difficult to access due to vessel mobility
    - Peroneal: Adjacent to intraosseous membrane, may be difficult to access due to depth
  - Access away from flexion points
  - Evaluate arterial patency with US
  - Access with US-guided micropuncture needle
    - Seldinger technique or
    - Double-wall puncture may be easier
      - Withdraw needle slowly, gently advancing 0.014-0.018" wire/probing for vessel lumen
  - Fluoroscopically monitor wire advancement
  - Advance low profile/microcatheter over wire; contrast confirming intraluminal location
    - Sheath placement is not routinely required
  - Deliver systemic anticoagulation (e.g., heparin) & vasodilators (e.g., nitroglycerin, verapamil)
  - Wire & catheter are advanced retrograde across lesion & through antegrade access, thus producing through-and-through access for angioplasty
- **Aortic access**
  - Access site
    - High access: Target T12 inferior endplate, skin entry point between left 12th rib & iliac crest
    - Low access: Target L3 inferior endplate
    - Endoleak repair: Target aneurysm sac
  - Sterilely prepare skin at planned entry point
    - If too medial, spinous process will block needle
    - If too lateral, may puncture kidney or be unable to reach aorta with needle length
  - Anesthetize skin with lidocaine
    - Anesthetize along intended needle course using 20-g spinal needle
  - Use #11 blade to make 5-mm skin nick
  - Introduce 18-g trocar translumbar needle
    - Advance medially toward edge of vertebral body
  - If vertebral body encountered, withdraw needle, change needle angle, redirect
  - Contact with aortic wall recognized by
    - Fluoroscopically seen deflection of calcification

    - Transmitted pulsations by needle
    - Confirmation via CT
  - Firmly advance needle 1 cm more into aorta; may encounter "release" of pressure
  - Remove stylet, confirm blood return
    - May be vigorous dribble rather than pulsatile
  - Introduce 0.035" guidewire through needle
  - Advance long access sheath into aorta

Alternative Procedures/Therapies

- "Cutdown" over target artery (e.g., femoral, brachial)
  - Provides direct arterial exposure; more invasive
    - Hemostatic control with vessel loops
  - Direct needle access vs. arteriotomy
  - Surgical arterial closure after access

POST PROCEDURE

Things to Do

- After completing transarterial procedure
  - Identify pulse prior to catheter/sheath removal
  - Check activated clotting time, deliver protamine as needed
  - **CFA: Manual compression for hemostasis**
    - Remove catheter/sheath as pressure applied
      - ☐ Compress both above & at puncture site
      - ☐ Maintain near-occlusive pressure for 2-3 min
      - ☐ Gradually reduce pressure over 15 min
      - ☐ If bleeding resumes, reapply pressure
    - **Do not** use sandbag over puncture site; may hide developing hematoma
    - Bedrest with leg immobile 6 hours afterwards; may ambulate with assistance after bedrest
    - May elevate head of bed 30°
    - Evaluate pulses, vital signs, access site at regular intervals; watch for developing hematoma
      - ☐ If hematoma, trace margins with indelible ink
      - ☐ Follow any hematoma size increase
      - ☐ Severe groin/back pain, vital sign deterioration worrisome for retroperitoneal hematoma; obtain emergency CT to exclude/confirm
      - ☐ Pulse loss, neurologic symptoms may require surgical exploration of access site
  - **CFA: Closure device for hemostasis**
    - Earlier ambulation than with manual compression
    - Variety of devices, methods of closure
  - **Radial artery access**
    - Nonocclusive hemostasis achieved with inflatable wrist band, 30-120 min
    - Band typically deflated over 15 min, if bleeding occurs band is reinflated for 20 min
    - Discharge 30 min after band removed
  - **Brachial artery access**
    - Manual pressure typically used for hemostasis
      - ☐ Reported use of closure devices: Decreased risk of hematoma, increased risk of thrombosis
    - Place arm in sling
    - Monitor for 2 hours prior to discharge
    - Perform nerve check (motor & sensory) along with arterial checks (radial & ulnar); neurological symptoms require immediate surgical consultation/evacuation
    - Advise use of sling & self-monitoring for nerve compression (e.g., pain, weakness) for 24 hours
  - **Translumbar access**: No compression required
    - Patient may experience mild backache
    - Check vital signs at regular intervals
    - Ambulation after 4-6 hours bedrest

OUTCOMES

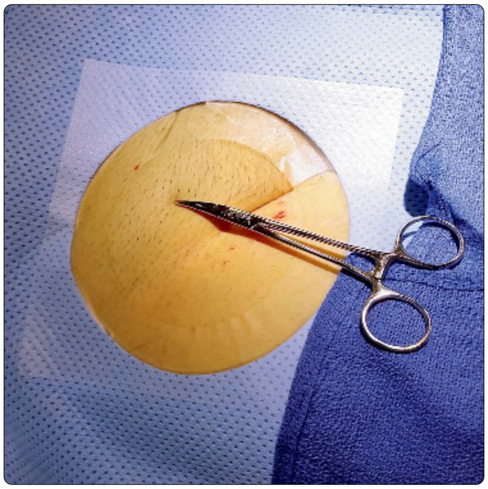
Complications

- Most feared complication(s)
  - **Femoral artery access**
    - Pseudoaneurysm formation
    - Retroperitoneal hematoma
      - ☐ Hematoma can extend above inguinal ligament
      - ☐ More frequent with double-wall puncture
      - ☐ Can occur with high femoral artery puncture
  - **Radial artery access**
    - Radial artery occlusion (6-10%)
      - ☐ Almost always asymptomatic due to patent ulnopalmar arch
    - Stroke: Exact incidence unknown, very small (< < 1%)
    - Pseudoaneurysm (< 1%)
    - Hematoma/bleeding (< 1%), more common in females
  - **Brachial artery access**
    - Stroke (incidence < 0.5%); related to catheter crossing great vessel origins
    - Median nerve injury: Direct puncture injury vs. expanding hematoma
    - Vessel injury or thrombosis; smaller vessel diameter are more prone to spasm
    - Female gender has increased complication risk
  - **Axillary artery access**
    - Hematoma may compress brachial plexus
      - ☐ Without surgical evacuation/arterial repair, permanent nerve deficit may occur
  - **Aortic access**
    - Pneumothorax, hemopneumothorax
      - ☐ May occur with high aortic access
- Other complications
  - **Femoral, brachial, axillary artery access**
    - Hematoma: Minor (2-10% incidence); major, requiring treatment (< 0.5% incidence)
    - Thrombosis/distal embolization (< 1% incidence)
    - Pseudoaneurysm (< 0.2% incidence)
    - Arteriovenous fistula (< 0.2% incidence)
    - Dissection (< 0.2% incidence)
      - ☐ Retrograde access dissection usually self-limited; antegrade blood flow compresses false lumen
  - **Aortic access**
    - Retroperitoneal hematoma
      - ☐ Usually small self-contained psoas hematoma
      - ☐ < 1% symptomatic
    - Needle injury to visceral artery

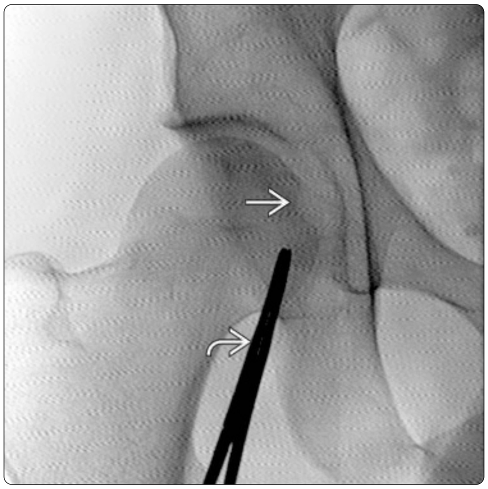
SELECTED REFERENCES

1. Fischman AM et al: A technical guide describing the use of transradial access technique for endovascular interventions. Tech Vasc Interv Radiol. 18(2):58-65, 2015

Step-by-Step: Femoral Artery Access (Marking Femoral Pulse)

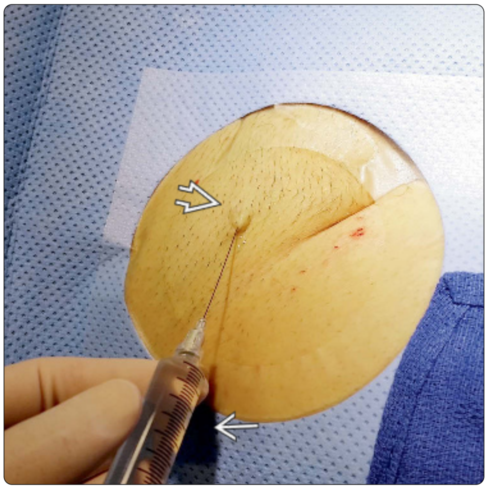


Step-by-Step: Femoral Artery Access (Fluoroscopic Confirmation)

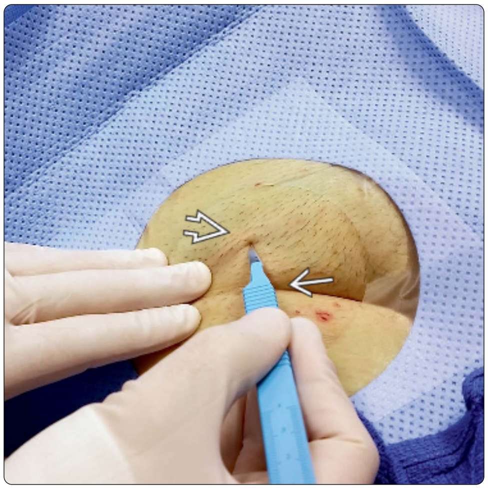


(Left) *After the common femoral pulse is palpated, a hemostat is used to mark the location on the skin.* **(Right)** *Fluoroscopy confirms that the hemostat* ➡ *(planned skin access point) is over the middle of the medial 1/3 of the femoral head, preventing either a high or a low puncture. The 45-70° angle of the percutaneous needle will result in arterial access* ➡ *slightly superior to the hemostat.*

Step-by-Step: Femoral Artery Access (Superficial Anesthesia)

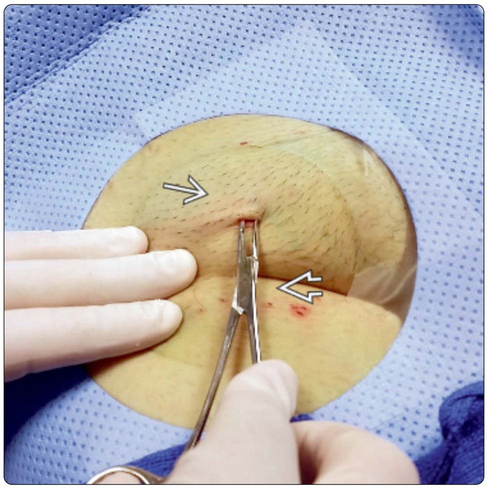


Step-by-Step: Femoral Artery Access (Superficial Nick)

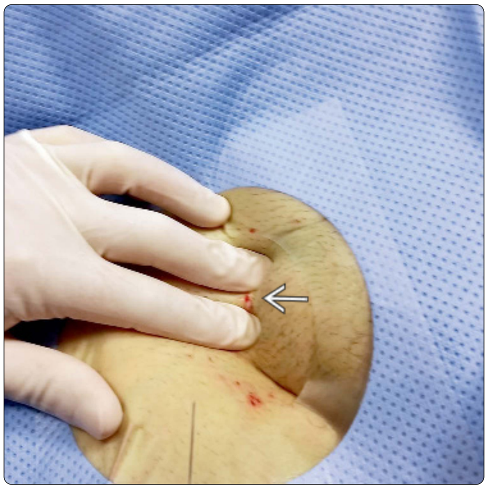


(Left) *Subcutaneous tissues are anesthetized with lidocaine* ➡*. A small (1-2 cm) subcutaneous wheal* ➡ *is first delivered, helping guide the location of the future skin nick. After waiting 5-10 seconds for the lidocaine to work, deep lidocaine (5-8 cc) is delivered medial & lateral to the planned access route.* **(Right)** *A #11 blade* ➡ *is used to make a shallow skin nick* ➡ *1-2 cm below the intended arterial site for retrograde access (above for antegrade). Some interventionalists may prefer to make the nick after needle access.*

Step-by-Step: Femoral Artery Access (Blunt Dissection)

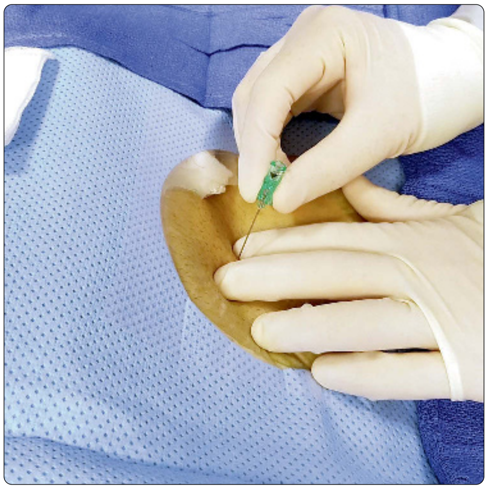


Step-by-Step: Femoral Artery Access (Palpating Pulse)

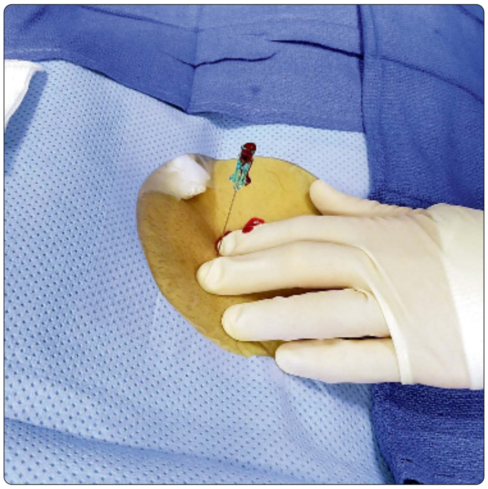


(Left) *The shallow skin nick prevents inadvertent cutting of the common femoral artery. The small incision can now be enlarged & deepened with blunt dissection* ➡ *of the soft tissues, performed with a hemostat* ➡*.* **(Right)** *In this example, US guidance was not utilized. Instead, the femoral pulse was palpated above & below the skin nick* ➡ *prior to attempting access.*

(Left) *The micropuncture needle is advanced toward the palpated CFA pulse at a 45-70° angle. If no blood is returned, continue advancing the until contacting the femoral head (lidocaine can be delivered via the needle). Lower the needle angle & slowly withdraw.* **(Right)** *At times, blood return will occur during needle withdrawal. If not, localize the pulse & readvance the needle, or consider using US. As the needle enters the arterial lumen, a loss of resistance may be felt & pulsatile bright red blood seen.*

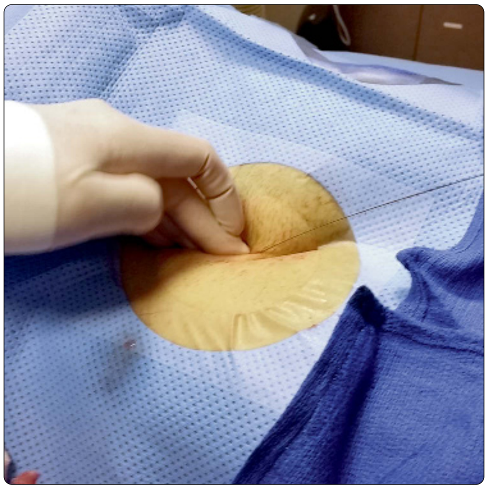


Step-by-Step: Femoral Artery Access (Advancing Micropuncture Needle)

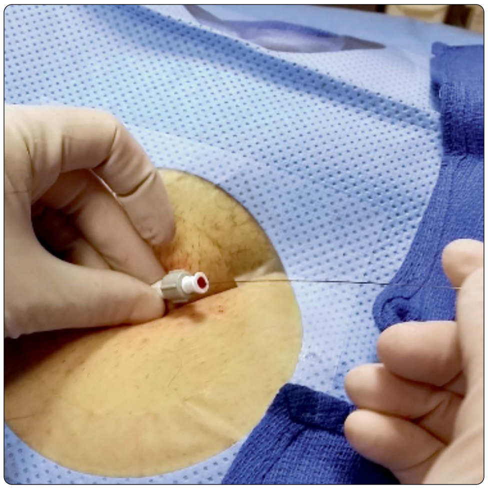


Step-by-Step: Femoral Artery Access (Accessing Artery)

(Left) *After obtaining access, an 0.018" guidewire is advanced through the micropuncture needle. Fluoroscopy can be used to visualize the guidewire path & confirm arterial placement. After the needle is removed over the guidewire, manual compression on the artery should be maintained to prevent hematoma.* **(Right)** *The transitional sheath is then advanced over the stabilized guidewire. Slight traction on the guidewire will straighten the wire & assist sheath advancement.*

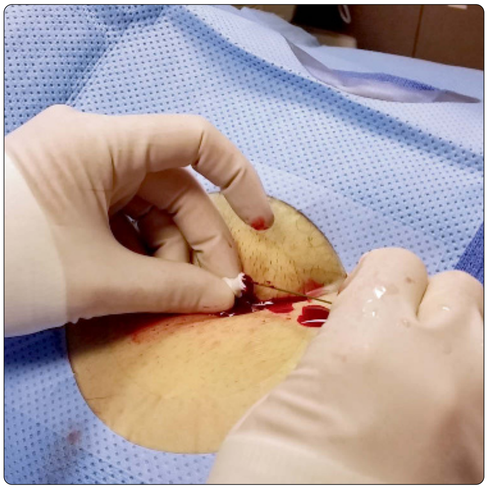


Step-by-Step: Femoral Artery Access (Advancing 0.018" Guidewire)

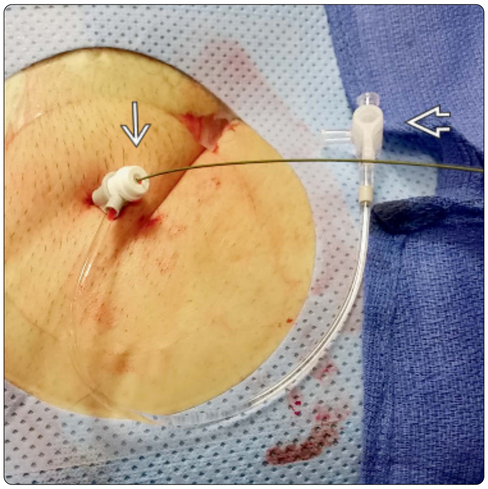


Step-by-Step: Femoral Artery Access (Advancing Transitional Sheath)

(Left) *After removing the guidewire & inner dilator, the 0.035" wire is advanced through the transitional sheath. Place your finger over the sheath to halt bleeding as needed.* **(Right)** *After removing the transitional sheath over the wire, the arterial sheath is advanced into place over the wire. The hemostatic valve ➡ minimizes blood loss, & the 3-way stopcock ➡ allows for both contrast injection through the sheath & connection to a pressure bag for continuous flushing of the sheath.*

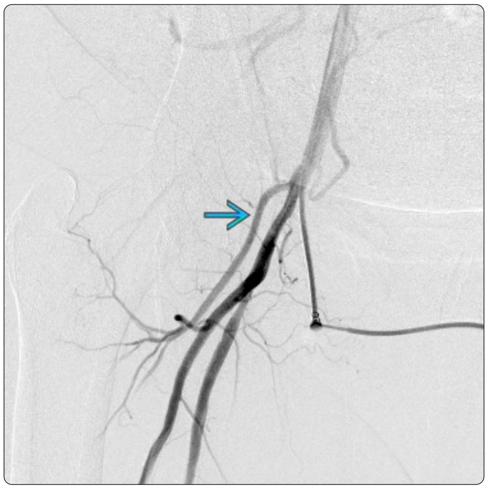


Step-by-Step: Femoral Artery Access (Advancing 0.035" Wire)

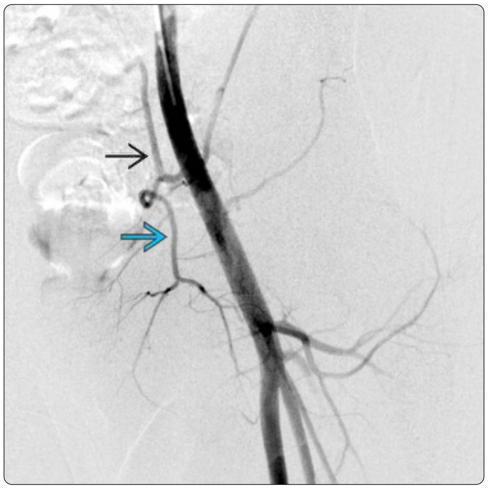


Step-by-Step: Femoral Artery Access (Placing Arterial Sheath)

Variant: Circumflex Femoral Artery

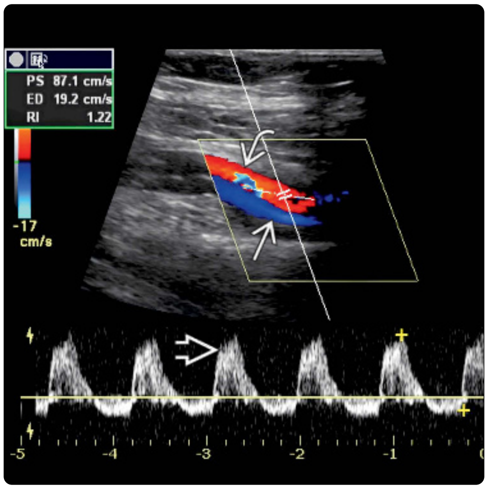


Variant: Obturator Artery

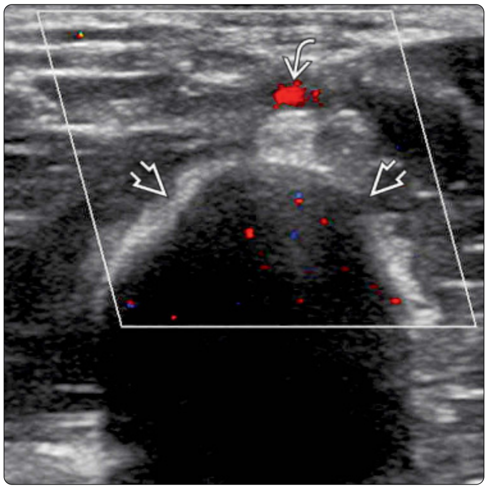


(Left) *Contrast injection through a CFA access sheath reveals a high take-off of the circumflex femoral artery →, typically arising from the profunda femoris.* **(Right)** *DSA shows an anatomic variant in which the obturator →, or an accessory obturator artery, arises from the inferior epigastric artery → (30% incidence). Variants can be inadvertently punctured during attempted access of the femoral artery or vein. Bleeding from this potential variant can occur in cases of pelvic ring fractures.*

Brachial Artery Access (US Evaluation)

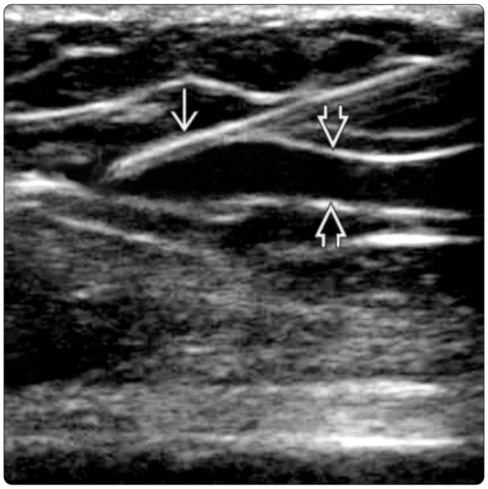


Brachial Artery Access (High Access)

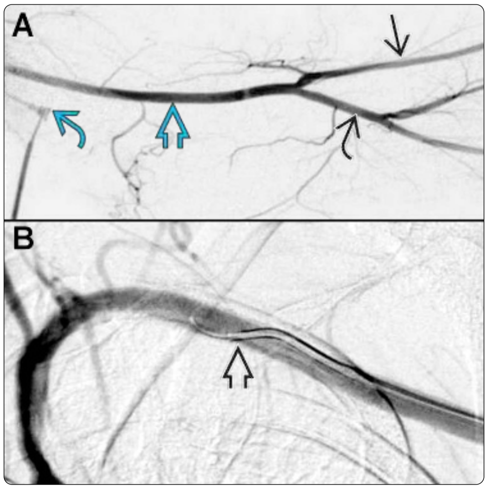


(Left) *US-guided arterial access shows that the brachial artery ↷ is superficial to the vein → & exhibits an arterial waveform ⇨. Spectral waveform suggests the proximal subclavian & axillary arteries are free of stenosis. US guidance is preferred for access with fewer complications, as the artery is small & prone to spasm.* **(Right)** *The close proximity of the high brachial artery ↷ to the humerus ⇨ can allow effective manual compression & hemostasis following access.*

Brachial Artery Access (US-Guided Access)

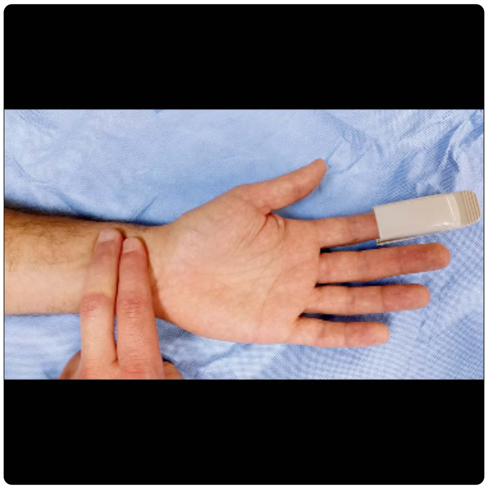


Brachial Artery Access (Angiography)

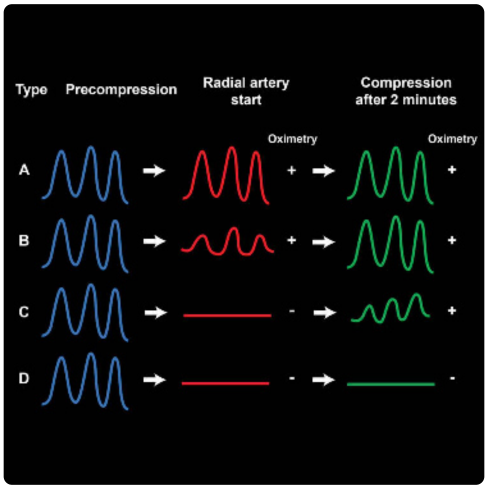


(Left) *Sagittal US shows the tip of a micropuncture needle → within the brachial artery lumen ⇨. US minimizes the risk of injuring the median nerve that runs adjacent to the artery.* **(Right)** *DSA (A) of the brachial artery ⇨ shows its division into the radial → & ulnar ↷ arteries. In this example, a sheath ↷ enters the high brachial artery. More centrally (B), a catheter ⇨ has been advanced over a J-tip guidewire into the subclavian artery.*

Step-by-Step: Radial Artery Access (Barbeau Maneuver)

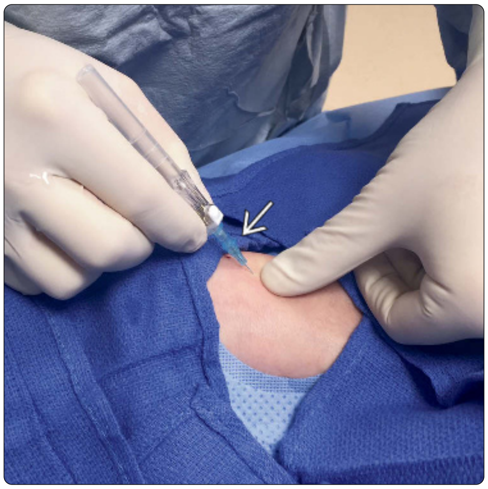


Step-by-Step: Radial Artery Access (Barbeau Graphic)

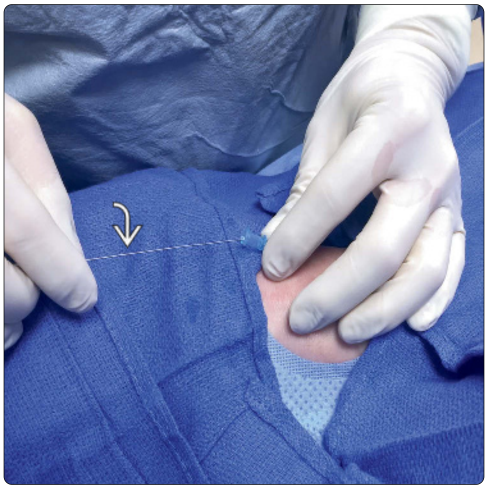


(Left) *The Barbeau maneuver involves placing the pulse oximeter on either the thumb or index finger, followed by examination of the pulse oximetry waveform before & after manually occluding the radial pulse for 2 minutes.* **(Right)** *Waveform types A, B, & C are consistent with a patent ulnopalmar arch. Type D waveform suggests an occluded ulnopalmar arch & is a contraindication to radial artery access.*

Step-by-Step: Radial Artery Access (Double-Wall Technique)

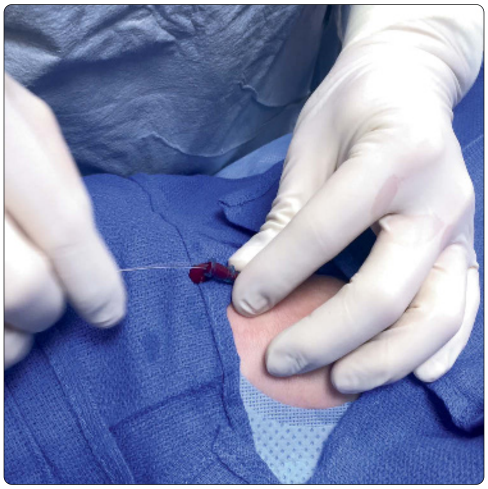


Step-by-Step: Radial Artery Access (Angiocath Withdrawal)

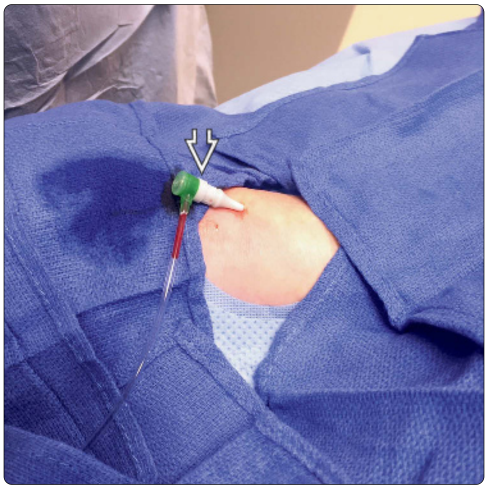


(Left) *In this example, the radial artery is accessed without US guidance using double-wall technique. Once the radial pulse is palpated, an Angiocath ➔ & needle are advanced completely through the artery.* **(Right)** *The needle is then removed & the Angiocath is slowly withdrawn. The wire ➔ is ready to be threaded through the access catheter as soon as pulsatile blood is encountered upon catheter withdrawal.*

Step-by-Step: Radial Artery Access (Percutaneous Wire Advancement)

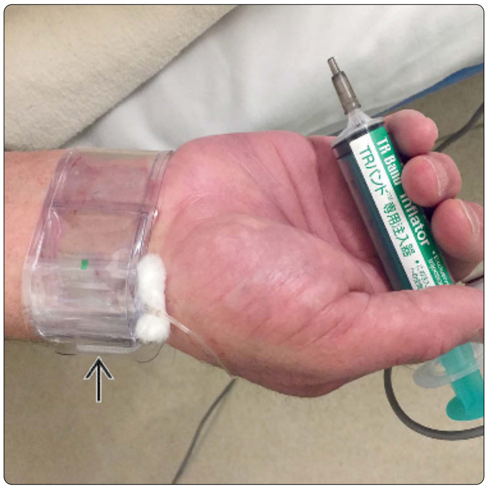


Step-by-Step: Radial Artery Access (Percutaneous Sheath Placement)

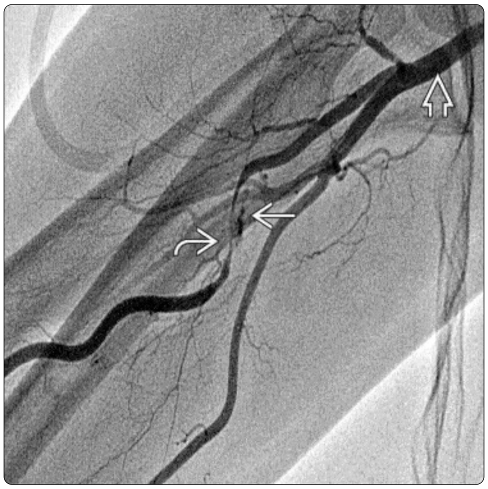


(Left) *Pulsatile blood confirms intraluminal arterial access. The Angiocath is stabilized, & the 0.018" wire is gently advanced.* **(Right)** *A sheath designed for radial access ➔ is advanced into place over the 0.018" wire. A cocktail of nitroglycerin, heparin, & verapamil is then injected through the sheath. This 5-Fr radial sheath is bored out to facilitate a larger 6-Fr inner diameter; however, this makes the sheath less rigid & not suitable for femoral access.*

Hemostasis: Postradial Artery Access

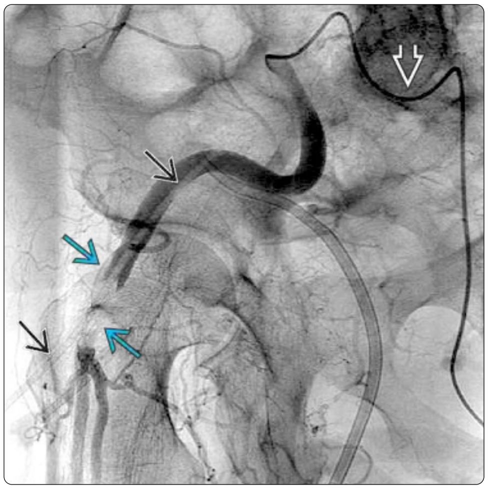


Complication: Postradial Artery Access

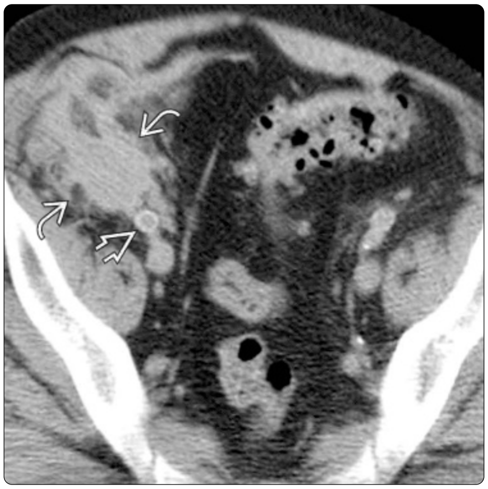


(Left) *Following the procedure, the sheath is removed & a nonocclusive wrist band* ➔ *applied for up to 2 hours. At times, the patient is asked to hold on object (syringe), occupying hand & minimizing movement during recovery period.* **(Right)** *An antegrade brachial* ⇨ *arteriogram shows radial artery contrast extravasation* ➔ *& accompanying spasm* ↷*. Access-related radial artery injury can occur but is usually self-limiting & almost always asymptomatic due to the intact ulnopalmar arch.*

Complication: Femoral Artery Access (Dissection)

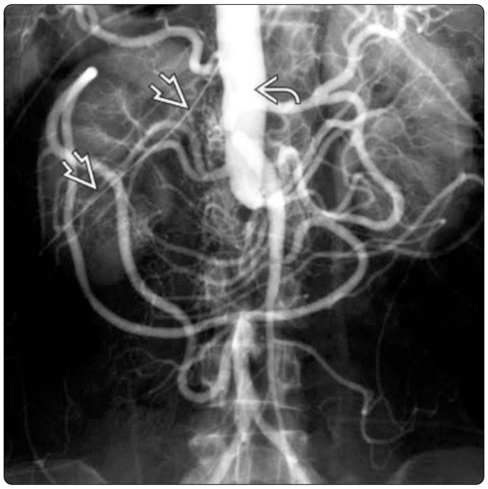


Complication: Femoral Artery Access (External Iliac Artery Sheath Placement)

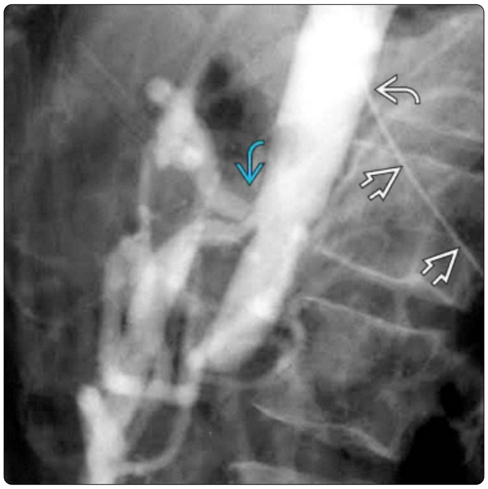


(Left) *Dissection* ➔ *of the right CFA occurred during percutaneous access & advancement of a sheath* ➔*. Arteriogram was obtained through a catheter* ⇨ *advanced via the left groin. Endovascular treatment options (e.g., prolonged balloon inflation, stent placement) were considered, but ultimately, the patient underwent surgical repair.* **(Right)** *This patient became hypotensive & tachycardic after high-access sheath removal. Axial CT reveals a pelvic hematoma* ↷ *adjacent to a bypass graft* ⇨*.*

Translumbar Arterial Access (AP)



Translumbar Arterial Access (Lateral)



(Left) *Abdominal aortogram in a prone patient shows the sheath* ⇨ *entering the aorta from the left at a point above the celiac trunk* ↷*. Translumbar access is typically performed via a left-sided paraspinal point of access so as to avoid the right-sided inferior vena cava.* **(Right)** *Lateral aortogram shows the translumbar sheath* ⇨ *entering the abdominal aorta posteriorly* ↷*, above the celiac trunk* ↷*. High lumbar puncture is used for aortic occlusive disease, while low puncture is more often used for post-EVAR endoleak repair.*

Closure Devices

KEY FACTS

TERMINOLOGY

- Closure device types and mechanisms of action
    - Active closure devices: Use suture, nitinol clip, mechanical sealant, or arterial tamponade
    - Assisted compression devices: Apply direct pressure to access site
    - Hemostasis pads and patches: Topical agent promotes vasoconstriction/clot formation

PREPROCEDURE

- Device indicated for hemostasis after arterial access
    - Permits intraprocedural anticoagulant/thrombolytic administration; hemostasis afterward
- Obtain DSA images of access site prior to closure
    - Shows any potentially complicating anatomy

PROCEDURE

- Sufficiently dissect skin entry for device insertion
- Active devices require guidewire or access sheath
- Pressure-assisted devices should not obliterate pulse
- Topical pads and patches are used with manual compression

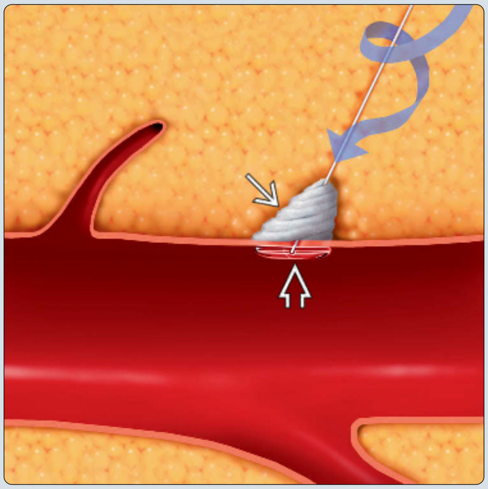
POST PROCEDURE

- Assessment before considering early discharge
    - Ability to ambulate without pain, bleeding

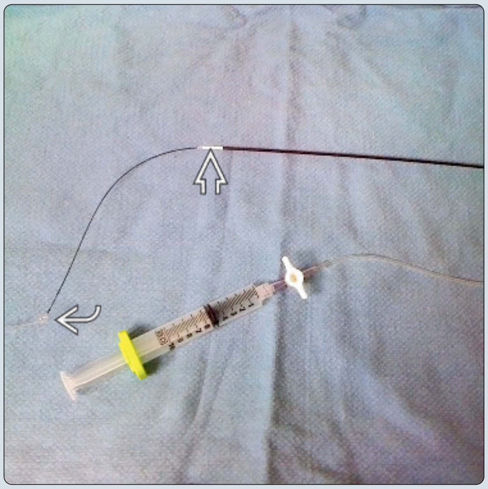
OUTCOMES

- **Most feared complication**
    - Obstructing intravascular foreign body
- **Expected outcomes**
    - Successful closure device deployment (96.4%)
    - Shorter time to hemostasis at access site
    - Decreased time to ambulation vs. manual compression

Mechanical Seal Closure Device

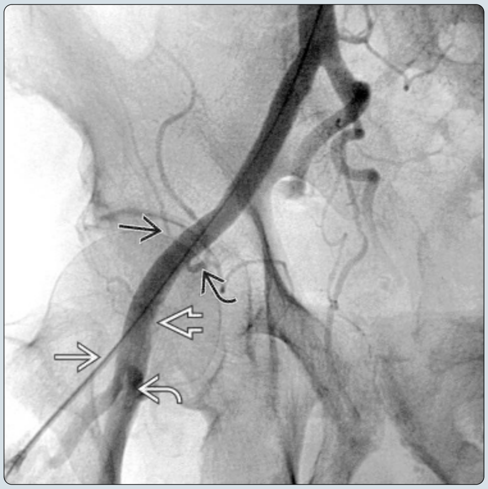


Mechanical Seal Closure Device

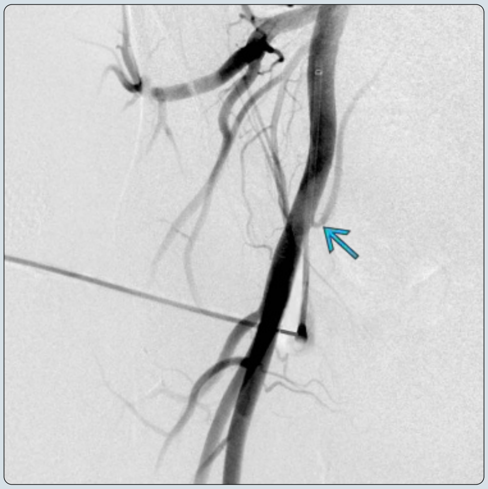


(Left) *Graphic of a mechanical seal-type closure device shows a bioabsorbable anchor ➡ within the vessel lumen & a collagen plug ➡ compressed against the outer arterial wall. These seal the arteriotomy to achieve hemostasis.* **(Right)** *Alternatively, a Mynx closure device uses an intravascular balloon ↪, inflated and withdrawn until it tamponades the arteriotomy internally, in place of bioabsorbable anchor. Extravascular polyethylene glycol sealant ➡ is then deposited, and the balloon is deflated and withdrawn.*

Obtain Angiogram Prior to Closure



Borderline High Arterial Access



(Left) *A sheath ➡ enters a disease-free femoral artery ➡ above the femoral bifurcation ↪ and below the inferior epigastric ⇨ and deep circumflex iliac ⇨ arteries at an ideal location for using a closure device.* **(Right)** *Arterial access is at the level of the inferior epigastric artery takeoff ⇨. Whether or not a closure device is utilized (operator preference), the patient must be closely observed to ensure intraabdominal hemorrhage and groin hematoma do not occur.*

TERMINOLOGY

Definitions

- **Active closure devices**
  - **Suture-mediated closure**
    - Perclose ProGlide (Abbott Vascular; Redwood City, CA)
      - ☐ Introduced over guidewire through arteriotomy
      - ☐ Nonresorbable polypropylene monofilament suture closes arteriotomy
      - ☐ Mechanism parallels surgical suture closure
      - ☐ Can close arteriotomies ranging in size from 5 to 21 French; 2 devices using preclose technique available for > 8-French size
      - ☐ ProStar XL available for arteriotomies up to 10 French in size
  - **Nitinol clip**
    - StarClose SE (Abbott Vascular)
      - ☐ Delivers nitinol clip to close access site
      - ☐ Can close arteriotomies up to 6 French in size
      - ☐ MR conditional following application
  - **Arteriotomy tamponade**
    - Catalyst (Cardiva Medical; Santa Clara, CA)
      - ☐ Device inserted through existing access sheath; sheath exchange not required
      - ☐ Nitinol disc expanded within vessel, then collapsed, & pulled through arteriotomy/tract
      - ☐ Extravascular tract exposed to hemostatic coating; promotes hemostasis, prevents oozing
      - ☐ Brief manual compression after disc withdrawal
      - ☐ Catalyst II & Catalyst III variants; Catalyst III adds protamine sulfate to neutralize heparin in access tract
      - ☐ Compatible with 5-French, 6-French, & 7-French vascular sheaths (≤ 15.7 cm in length)
  - **Mechanical seal**
    - Angio-Seal (St. Jude Medical; St. Paul, MN)
      - ☐ Extravascular collagen sponge connected by self-tightening suture to intravascular polymer anchor (absorbable)
      - ☐ Creates "sandwich" at arteriotomy between anchor & collagen sponge
      - ☐ All components absorbed within 60-90 days
      - ☐ 2 device sizes: Maximum 6-French or 8-French arteriotomy
      - ☐ Access 1 cm proximal to previous access site if repuncture < 90 days
    - MYNX ACE (AccessClosure; Mountain View, CA)
      - ☐ Extravascular polyethylene glycol sealant deposited, seals access tract/arteriotomy
      - ☐ Fully absorbed in 30 days
      - ☐ Device inserted through existing access sheath; sheath exchange not required
      - ☐ Compatible with 5-French, 6-French, & 7-French vascular sheaths (≤ 15.7 cm in length)
      - ☐ Intravascular occlusion balloon used during sealant deployment
    - ExoSeal (Cordis; Miami Lakes, FL)
      - ☐ Extravascular polyglycolic acid plug sealant
      - ☐ Fully absorbed in 60-90 days
      - ☐ Device inserted through existing access sheath; sheath exchange not required
      - ☐ Compatible with 5-French, 6-French, & 7-French vascular sheaths (≤ 12 cm in length)
    - Femoral Introducer Sheath & Hemostasis (FISH) (Morris Innovative; Bloomington, IN)
      - ☐ Closure device placed during initial access
      - ☐ Ribbon of small intestinal submucosa mounted on sheath introducer; creates resorbable plug
      - ☐ Can close arteriotomies up to 8 French in size
      - ☐ Can be used in vessels as small as 3 mm
- **Assisted compression devices**
  - **Pressure-assisted devices**
    - Safeguard (Datascope; Mahwah, NJ)
      - ☐ Pneumatic compression device
      - ☐ Inflatable "bladder" with adhesive backing
      - ☐ When inflated, applies direct pressure
      - ☐ 12-mm & 24-mm sizes available
    - FemoStop (St. Jude Medical)
      - ☐ Pneumatic compression device
      - ☐ Digital manometer; transparent, inflatable dome
    - QuicKlamp (TZ Medical; Portland, OR)
      - ☐ Mechanical compression clamp device
      - ☐ Uses compression discs
      - ☐ May attach hemostasis pad to disc
  - **Radial artery compression devices**
    - Safeguard Radial (Merit Medical; South Jordan, UT)
      - ☐ Pneumatic compression device
      - ☐ Clear window for visualization of puncture site
      - ☐ Uses standard Luer valve
    - TR Band (Terumo Medical; Somerset, NJ)
      - ☐ Pneumatic compression device
      - ☐ Transparent structure for visual control of puncture site
      - ☐ Velcro straps
    - RadiStop (St. Jude Medical)
      - ☐ Pneumatic compression device
      - ☐ Support plate enables controlled positioning of patient's wrist
    - RadAR (Advanced Vascular Dynamics; Portland, OR)
      - ☐ Strap with adjustment knob & movable compression pad that applies direct pressure to puncture site
    - RADstat (Merit Medical)
      - ☐ Support base & straps provide immobilization of wrist & adjustable direct pressure on puncture site
- **Topical hemostasis pads & patches**
  - Chito-Seal (Abbott Vascular)
    - Positively charged chitosan molecules attract negatively charged red blood cells/platelets
  - Clo-Sur P.A.D. (Scion Cardio-Vascular; Miami, FL)
    - Chitosan (N-acetyl glucosamine-containing glycosaminoglycan)
  - D-Stat (Vascular Solutions; Minneapolis, MN)
    - Lyophilized pad with thrombin, Na^+ carboxymethyl cellulose, Ca^{++} chloride
  - V+Pad (Angiotech; Vancouver, BC, Canada)
    - D-glucosamine-enriched gauze fibers attract platelets for more rapid plug formation
  - Syvek patch (Marine Polymer Tech; Danvers, MA)

    - Poly-N-acetyl glucosamine; promotes clot formation/local vasoconstriction
  - SafeSeal (Medrad/Possis; Warrendale, PA)
    - Bioabsorbable desiccant; enhances clotting
- **Hybrid**
  - Axera (Arstasis; Fremont, CA)
    - Access/closure device placed during initial access
    - Creates pathway traversing artery at shallow angle
      - ☐ Uses hydrostatic forces to facilitate arterial closure when sheath withdrawn

PREPROCEDURE

Indications

- Hemostasis following percutaneous arterial access
  - Most devices designed for use after 5- to 8-French access
  - Preclose technique using suture-mediated closure device for larger access sheaths (up to 21 French)
    - Application for endovascular aneurysm repair
  - Patients on anticoagulants
    - Permits intraprocedural administration of anticoagulants, thrombolytics
    - Provides hemostasis that may not be achieved with manual compression

Contraindications

- Arteriotomy larger than device specifications
  - Generally ≤ 8 French
  - Perclose ProStar XL can be used for arteriotomies 8.5-10.0 French
  - Preclose technique for larger arteriotomies
    - Requires device placement (typically 2) prior to introducing large access sheath; advanced planning
- Heavily calcified femoral artery plaque (suture-mediated devices)
  - Suture-mediated devices; needles may not puncture heavy calcification
  - Nitinol clip device; clip may not adequately grab calcified tissue
- Small-caliber/severely diseased arteries
- Infection
- Planned vascular surgery at access site
  - Collagen sponges, other sealants incite local inflammatory reaction
  - Closure with suture-mediated device may incite periadventitial fibrosis, creating fibrous hood around suture & vessel
  - Closure with nitinol clip device does not preclude surgery/repeat access
- Antegrade puncture (relative contraindication)
- Severely obese patients
  - However, some studies have shown better outcomes with closure device vs. manual compression
- Known allergy to device components (collagen, nitinol, glycol, etc.)

Preprocedure Imaging

- Obtain DSA images of access site prior to closure
  - Shows catheter/sheath position in artery; obtain in right anterior oblique or left anterior oblique projection
  - Shows any potentially complicating anatomy
    - Stenosis, eccentric plaque
    - Unfavorable access at arterial branch point
    - Access in superficial femoral artery rather than common femoral artery
    - High arterial puncture (above inguinal ligament, inferior epigastric artery)
  - Avoid use in small-caliber vessel (< 5 mm)

Getting Started

- Things to check
  - Confirm sterility maintained at access site
    - Repeat sterile skin preparation if necessary
  - Allergic history
    - Usually more pertinent with topical pads/patches
    - Some active devices have collagen, nitinol, glycol
- Medications
  - Lidocaine 1-2%
    - May reanesthetize access site prior to closure
  - May consider antibiotic prophylaxis
- Equipment list
  - Heparinized saline flush
  - Guidewire for insertion into access sheath
  - Closure device

PROCEDURE

Equipment Preparation

- Flush sheath prior to introducing guidewire/device
- Any necessary flushing of closure device component(s)

Procedure Steps

- **General**
  - Initial access
    - Consider ultrasound-guided access to avoid sidewall puncture
    - Use 21-gauge micropuncture needle in case of double wall puncture
  - Sufficiently dissect access site for device insertion
    - Dissect skin entry site with hemostat
    - Dissect catheter/sheath tract if necessary
- **Suture-mediated/nitinol clip device**
  - Introduce guidewire through access sheath/catheter
  - Remove sheath; introduce closure device over wire
    - Sequentially follow steps to deploy suture/clip
  - Apply manual compression for 2 minutes
    - Confirms hemostasis
- **Arteriotomy tamponade device**
  - Must have access sheath in place
  - Introduce device through, then remove sheath
  - Expand disc within vessel lumen
  - Pull device snug, secure at skin with clamp
  - Leave device indwelling for 10 minutes
  - Collapse disc, withdraw device/apply light pressure
- **Mechanical seal device**
  - Introduce guidewire through access sheath/catheter
  - Remove access sheath; introduce device sheath
  - Introduce device through sheath
    - Sequentially follow steps to deploy components
  - Remove device, apply light pressure
- **Pressure-assisted devices**
  - Must be placed directly over access site
  - Inflate/secure device over access site

    - Should compress, but not obliterate pulse
- **Topical pads/patches**
  - May require "activation"
    - Wet with saline or trace blood from access tract
  - Place pad/patch directly over access site
  - Manual compression with pad/patch beneath fingers

Findings and Reporting

- Describe device used, where deployed
  - Important to document for potential future access
- Note any device malfunction, failed hemostasis
- Describe any device-related complications
  - Note any required corrective actions

Alternative Procedures/Therapies

- Radiologic
  - Standard manual compression for hemostasis
- Surgical
  - Primary surgical suture closure of arteriotomy

POST PROCEDURE

Things to Do

- Manually compress access site after active closure
  - Light to moderate pressure for brief period
  - May not be necessary if no oozing from tract
- Apply sterile dressing over access site
- Assessment before considering early discharge
  - Ability to ambulate without pain, bleeding
  - Any evidence of expanding hematoma
- Educate patient regarding access site
  - Wound care
  - Signs/symptoms of delayed complications

Things to Avoid

- Repeat arterial access (same site) in short time frame
  - May be problematic with mechanical seal devices
    - Plug deposited outside vessel
    - Inflammatory reaction at closure site
  - Typically is not issue with suture/clip device

OUTCOMES

Problems

- Closure device use increases procedure costs
  - Shorter stay, fewer overnight admissions may offset
- Closure device complication rate slightly higher with interventional vs. diagnostic procedures
  - Probably related to larger sheath sizes
- Slightly increased risk of requiring surgery for arterial complications with closure device use
  - Rate of 0.7% vs. 0.4% with manual compression

Complications

- Most feared complication(s)
  - Obstructing intravascular foreign body (FB)
    - Improper deployment of mechanical seal device
      - Incorrectly positioned intravascular component
      - Extravascular plug can become intravascular
    - Can cause acute limb ischemia (0.3%)
      - Surgical embolectomy may be required
      - Stent to displace FB, depending on location
- Immediate/periprocedural complication(s)
  - Bleeding (4%)
  - Hematoma (5%)
  - Delayed bleeding upon ambulation
- Delayed complication(s)
  - Soft tissue/vascular infection (0.6%)
    - May require IV or oral antibiotic treatment
  - Granulation tissue/scar at access site
    - Suture device can create fibrous cap
    - Can complicate vascular surgical procedures
  - Inflammatory reaction in soft tissues/artery
    - Most common with mechanical seal devices
    - Can complicate vascular surgical procedures
    - May preclude repeat arterial access
  - Pseudoaneurysm (0.7%)
  - Arterial stenosis

Expected Outcomes

- Successful deployment of active closure device (96.4%)
- Shorter time to hemostasis at access site
- Decreased time to ambulation vs. manual compression
  - Some report 1-hour postprocedure ambulation
  - Typically 2-4 hours to ambulation
- Subjective reports of less pain vs. manual compression

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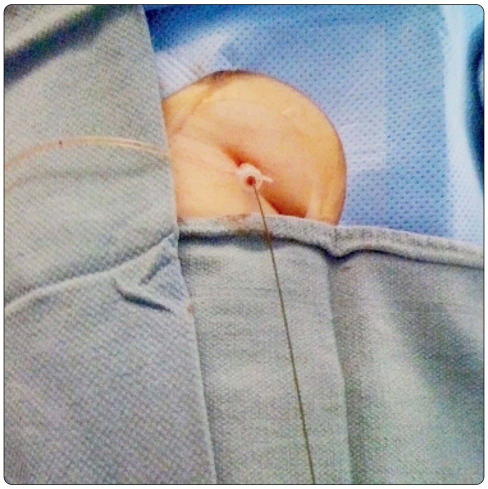
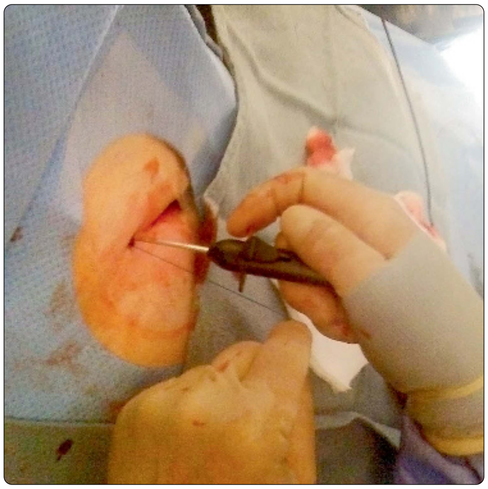
(Left) *Some vascular closure devices, such as the Catalyst, ExoSeal, and Mynx, are designed to be deployed using the initial procedure access sheath.* **(Right)** *An intraoperative photograph was obtained during deployment of a suture-mediated closure device. The sheath has been removed. Each closure device has multiple deployment steps that are unique to that closure device and must be closely replicated.*

Access Sheath

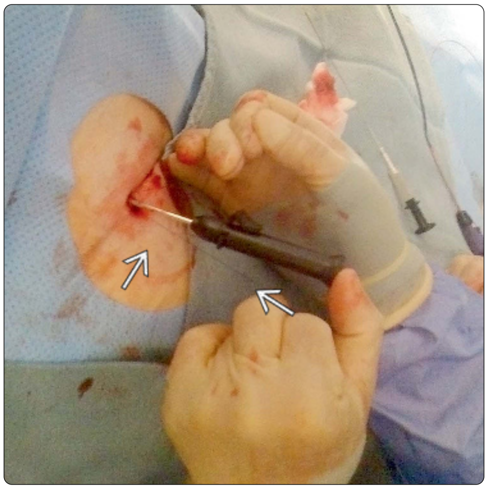


Suture-Mediated Closure Device

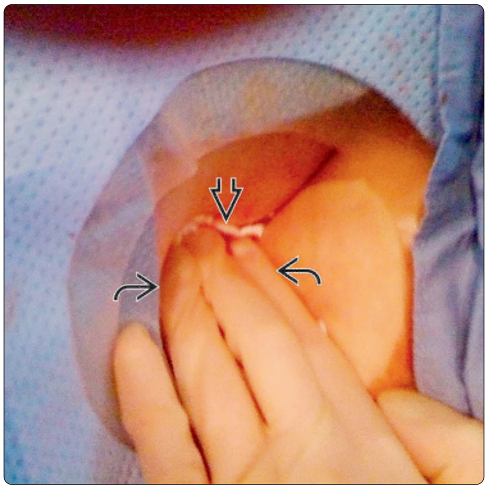


(Left) *During deployment of a PerClose closure device, sutures ➡ are deployed via a stepwise process and then trimmed below the skin. Some devices use absorbable sutures or compressive devices; others employ permanent metal.* **(Right)** *The photograph shows manual compression assisted by a topical hemostasis pad ⇨. The operator's fingers ⇨ compress directly over the point of arterial access. Topical hemostasis pads are composed of elements that are designed to promote clot formation and are activated upon contact with blood.*

Suture-Mediated Closure Device

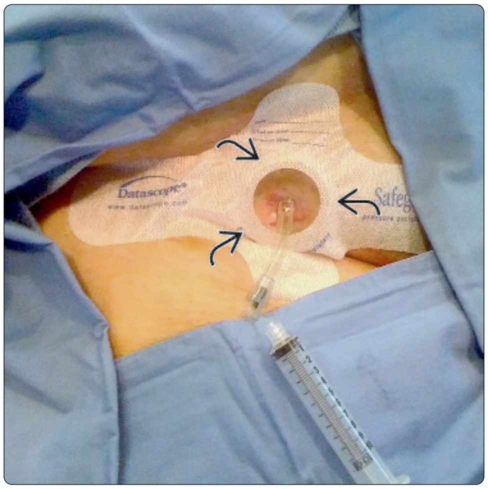


Topical Hemostasis Pad

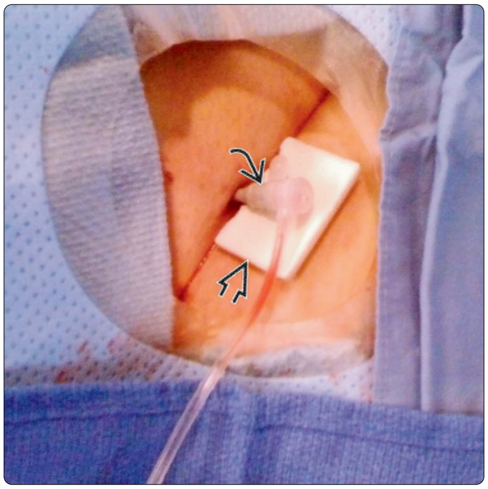


(Left) *A Safeguard compression device with an inflatable "bladder" ⇨ and adhesive backing has been placed over the femoral artery.* **(Right)** *Intraoperative photograph shows that a topical hemostasis pad ⇨ has been placed just beneath the femoral access sheath ⇨. As the sheath is removed, the pad is positioned directly over the skin entry point.*

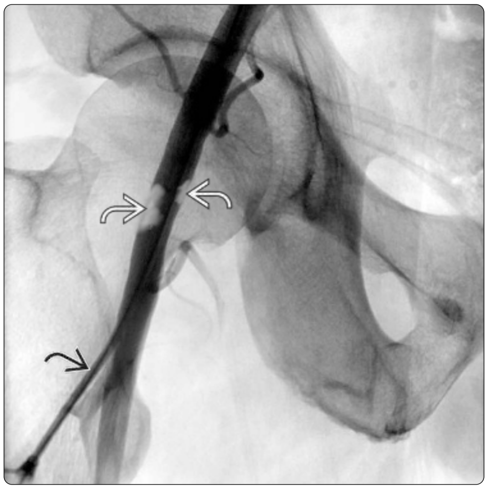
Assisted Compression Device



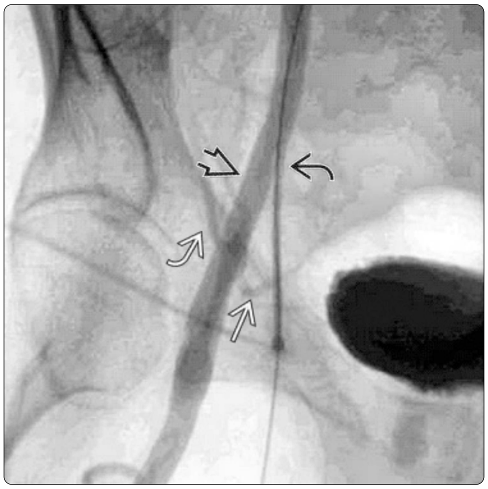
Topical Hemostasis Pad



Contraindication to Closure Device

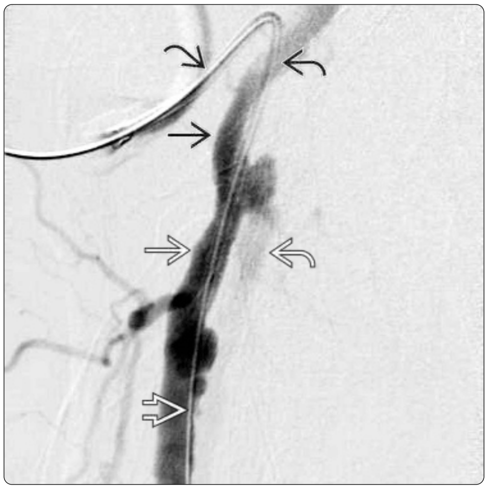


High Arterial Puncture

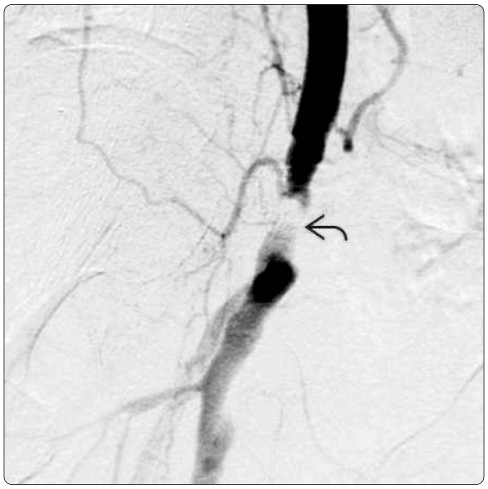


(Left) *Two focal areas* ➡ *of eccentric atherosclerotic plaque result in a stenosis just above the arterial access sheath* ⇨*. Closure device use is contraindicated in severely diseased or very small arteries.* **(Right)** *Angiography shows that the entry point* ⇨ *of a sheath is in the external iliac artery* ⇨ *above the inguinal ligament (marked by the deep circumflex iliac* ➡ *and inferior epigastric* ➡ *arteries). It is difficult to achieve hemostasis with either manual compression or a closure device, as the artery is mobile in the pelvis.*

Complication: Superior Femoral Artery Access

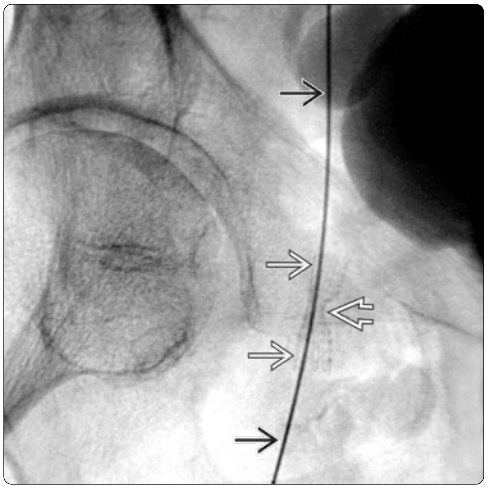


Complication: CFA Defect

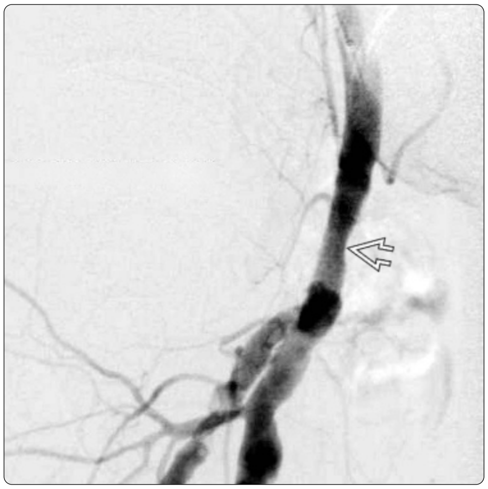


(Left) *DSA shows common femoral artery* ⇨ *bifurcation into superficial* ➡ *& profunda* ➡ *femoral arteries. A vascular sheath* ⇨ *& guidewire* ➡ *enter the superficial femoral artery in antegrade fashion for a planned infrainguinal intervention.* **(Right)** *Mechanical seal closure device was used for hemostasis. Shortly afterward, the patient had severe leg pain & pulse loss. DSA shows a filling defect* ⇨ *in the right common femoral artery (CFA) where the closure device was deployed, representing the collagen plug.*

Complication: Covered Stent Deployment



Complication: Luminal Caliber Restored



(Left) *A guidewire* ⇨ *was successfully advanced across the occluding intraluminal collagen plug in the CFA. A covered stent* ➡ *was positioned, bridging the occlusive collagen plug. Note the waist-like deformity* ➡ *of the covered stent.* **(Right)** *Following covered stent placement, an angioplasty balloon was used to distend the endoprosthesis within the CFA. This successfully compressed the collagen plug and restored a normal luminal caliber* ➡ *to the CFA.*

KEY FACTS

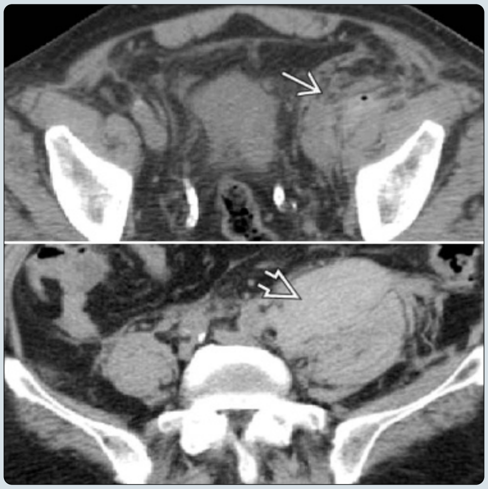
TERMINOLOGY

- **Hematoma**: Extravascular blood collection
- **Pseudoaneurysm (PSA)**: Contained arterial "rupture" at percutaneous access site
- **Arteriovenous fistula (AVF)**: Direct abnormal connection between artery and vein; variable size/severity
- **Arterial dissection**: Tear in arterial intima
- **Vessel thrombosis**: Can occur due to dissection, embolization, or in situ thrombus formation

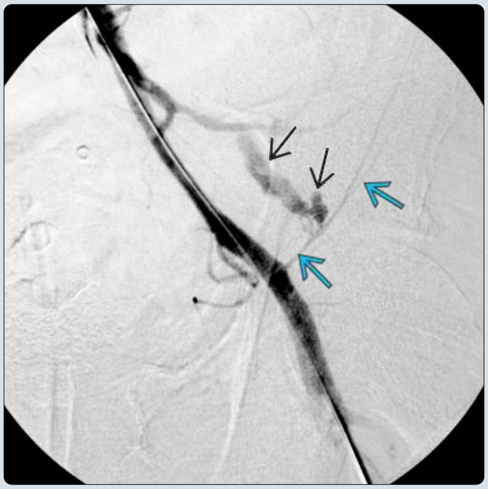
PROCEDURE

- **Hematoma**
  - Observation if small and stable
  - Percutaneous aspiration/drainage if compressive symptoms without evidence of active bleeding
  - Endovascular coiling/stenting to treat underlying vessel injury
  - Surgical evacuation if rapidly expanding/pulse loss
- **PSA**
  - < 1 cm: May resolve spontaneously
  - 1-4 cm: US-guided compression
    - Technical success: 63-88%
    - Mean compression time: 30-44 min
  - 1-6 cm: US-guided thrombin injection
    - Technical success: 93-100%
- **AVF**
  - Small: Up to 1/3 may spontaneously close
  - Large: Consider embolization vs. covered stent
  - Surgical repair if high risk of endovascular treatment
- **Arterial dissection**
  - Focal/nonocclusive: Prolonged balloon occlusion, systemic anticoagulation
  - Extensive/occlusive: Stenting
- **Vessel thrombosis**
  - Systemic anticoagulation
  - Pharmacomechanical ± catheter-directed thrombolysis
  - Surgical thrombectomy

(Left) *An axial NECT obtained in a patient who became hypotensive and tachycardic after a left transfemoral arteriogram shows a left iliopsoas hematoma ➡ with retroperitoneal extension ➡ up to the level just below the aortic bifurcation.* **(Right)** *Left common iliac DSA in the same patient shows contrast extravasation ⇨ originating from the deep circumflex iliac artery ⇨, corresponding to the site of hematoma seen on NECT.*

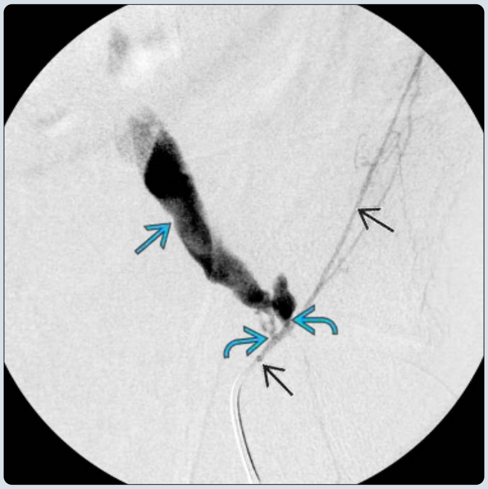


Hematoma: Iatrogenic Arterial Injury

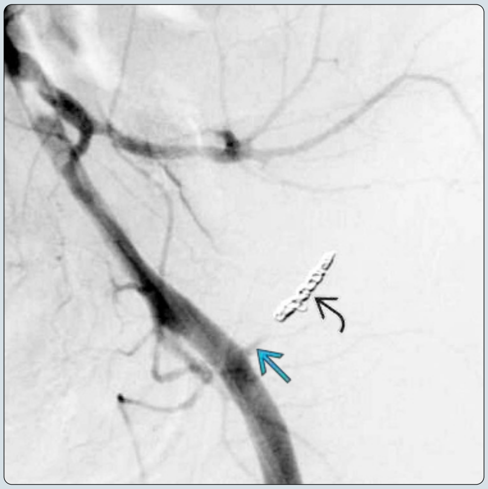


Hematoma: Iatrogenic Arterial Injury (Ipsilateral Iliac Artery DSA)

(Left) *DSA following selective catheterization of the deep circumflex iliac artery ⇨ again demonstrates contrast extravasation ⇨, which appears to involve 2 separate areas ↪ of the deep circumflex iliac artery.* **(Right)** *DSA after embolization of the distal deep circumflex iliac artery ↪ confirms cessation of the active extravasation. Coils were subsequently placed proximal to the site of injury ⇨ to prevent antegrade perfusion of the artery and rebleeding.*



Hematoma: Iatrogenic Arterial Injury (Ipsilateral Deep Circumflex Iliac DSA)



Hematoma: Iatrogenic Arterial Injury (Postcoil Embolization DSA)

Access Site Complications Management

TERMINOLOGY

Definitions

- **Hematoma**: Extravascular blood collection from continued bleeding at access site
    - Concern for active bleed → apply pressure
    - Most common minor complication
        - Incidence of up to 5% (but < 1% severe)
    - Extremity: Involving common femoral, brachial, or axillary arteries
        - Small: Subcutaneous perivascular soft tissues
            - Mild discomfort, ecchymosis
            - Self-limited, conservative treatment
        - Large: Extensively involves subcutaneous tissues
            - Severe groin/arm pain, massive swelling
            - May cause limb ischemia, nerve compression, or skin necrosis
            - Drainage vs. endovascular or surgical treatment
    - Retroperitoneal: Extension into retroperitoneal soft tissues of pelvis/abdomen
        - Associated with double wall and high punctures
        - May cause hemodynamic compromise and death
        - Exclude/address possible active bleed
            - Arterial bleed → angiography and embolization
            - Venous bleed → reverse anticoagulants, consult surgery
- **Pseudoaneurysm (PSA)**: Contained arterial "rupture" at access site
    - Most common major complication
        - Incidence: 0.05-2.00% after diagnostic catheterization
        - Increases to 2-6% when intervention performed
    - Occurs when arterial puncture does not adequately seal
        - Pulsatile blood tracks into and is contained in perivascular space; assumes sac-like configuration
            - Does not contain all 3 layers of arterial wall
        - Connecting tract persists between PSA and feeding vessel (usually common femoral artery)
    - Variable size and severity
        - < 1 cm: May resolve spontaneously
        - > 1 cm: Usually require treatment
            - US-guided compression: 1-4 cm
            - US-guided thrombin injection: 1-6 cm
            - Surgical repair: > 6 cm or after rupture
- **Arteriovenous fistula (AVF)**: Direct abnormal communication between artery and vein
    - Incidence of up to 0.9%
    - May be isolated or associated with PSA
    - Variable size and severity
        - Small: Up to 1/3 of AVFs may spontaneously close
        - Large: May cause hemodynamically significant left-to-right shunt with associated side effects
            - Surgical repair
            - Endovascular coiling if adequate length
            - Arterial covered stent occlusion for nonsurgical candidates
- **Arterial dissection**: Tear in arterial intima, creating false passage for blood
    - Incidence of < 0.5%
    - Variable severity
        - Focal, nonflow limiting: Usually self-resolve
            - Observation, systemic anticoagulation
        - Flow limiting: Can cause arterial occlusion/limb ischemia; require treatment
            - Focal: Prolonged endovascular balloon occlusion
            - Extensive (involving iliac arteries): Endovascular stent placement
- **Vessel thrombosis**: Can occur due to dissection, embolization, or in situ thrombus formation
    - Incidence of < 0.5%
    - Variable severity
        - Nonocclusive: Systemic anticoagulation
        - Occlusive: Endovascular thrombolysis vs. open thrombectomy

PREPROCEDURE

Indications

- **Hematoma**
    - Extremity
        - Vascular compression: Limb ischemia, deep venous thrombosis formation
        - Nerve compression: Sensorimotor deficit
    - Retroperitoneal hemorrhage/hematoma
        - Hemodynamic compromise, potentially fatal
- **PSA**
    - Size > 2 cm or after failed conservative management
    - Sensorimotor deficit
    - Severe pain
- **Arterial laceration**
    - Active bleed
- **AVF**
    - Large or enlarging
    - Symptomatic: Distal ischemia, distended veins, high-output cardiac failure
- **Arterial dissection**
    - Flow limiting, extending over time
    - Antegrade typically more concerning than retrograde
- **Vessel thrombosis**
    - Occlusive &/or extensive
    - Symptomatic

Contraindications

- **Hematoma**
    - Concern that aspiration may induce rebleed
        - Aspiration of hematoma decreases pressure/tamponade within potential space
- **PSA**
    - General: Active infection at access site, hemodynamic instability, skin necrosis
    - US-guided compression: Size > 4 cm
    - US-guided thrombin injection: Lack of discernible neck or neck involving > 50% of base of PSA

Preprocedure Imaging

- **US**: Preferred in hemodynamically stable patients
    - Determine type of complication
        - PSA: Classic swirling flow ("yin-yang" sign)
        - AVF: Vein with arterial waveform
    - Characterize morphology
        - PSA: Sac size, neck length, feeding vessels
        - AVF: Size, involved vessels, coexistent PSA

- **CT**: Preferred in hemodynamically unstable patients or if US unable to visualize complication
    - Characterize size/extent of hematoma
        - Local vs. retroperitoneal extension
        - Compression of adjacent structures
        - Identify and localize active extravasation (CTA)
    - Evaluate vessel integrity
        - Injury → contrast extravasation, hematoma formation
        - Dissection → visualization of flap, determination of flow, extent of propagation
    - Determine vessel patency
        - Occlusive vs. nonocclusive thrombus
        - Evaluate for distal embolization or clot propagation

Getting Started

- Things to check
    - Clinical history and physical examination
        - Active anticoagulation
        - Neurological evaluation
        - Detailed distal pulse examination
    - Labs and medications (if pursuing endovascular treatment), based upon "moderate risk of bleeding" per SIR consensus guidelines
        - Laboratory review
            - Complete blood count: Platelet count > 50,000/μL
            - International normalized ratio ≤ 1.5
        - Medications
            - Ticlopidine: Withhold 7 days before procedure
            - Dabigatran and fondaparinux: Withhold 2-3 days before procedure (or 3-5 days if CrCl < 50 mL/min)
            - Clopidogrel: Withhold 5 days before procedure
            - Low molecular weight heparin (therapeutic): Withhold 12 hours before procedure
            - Aspirin: Do not withhold
    - Antibiotic prophylaxis: Not routinely recommended per SIR guidelines, unless placing endograft
    - Informed consent: Specific considerations
        - Failure of percutaneous/endovascular treatment, need for surgical treatment
        - Sequela of vascular occlusion, including limb ischemia
- Equipment list
    - **Percutaneous aspiration or drainage (hematoma)**
        - US or CT guidance depending on location
        - Access needle: 18-20 gauge
        - 0.035" guidewire (e.g., Amplatz, Rosen)
        - 8- to 14-Fr dilators as appropriate
        - 8- to 14-Fr locking pigtail catheter
    - **US-guided compression (PSA)**
        - US with appropriate transducer
            - Most common: Linear array transducer with frequency of 4-7 MHz
    - **US-guided thrombin injection (PSA)**
        - US with linear array transducer
        - Small-caliber echogenic access needle (21-22 gauge)
        - 1-mL syringes (tuberculin syringe)
        - Thrombin (reconstituted in 1,000 U/mL concentration)
            - Off-label; label warning "not for intravascular injection"
            - Typically requires very small volumes (0.2-0.5 cc)
    - **Endovascular procedures**
        - Vascular access sheath
        - Guidewires: 0.035", angled/straight hydrophilic, stiff
        - Catheters: Flush, selective, &/or microcatheters
        - **Embolization (hematoma, AVF, laceration)**
            - Temporary embolic agent: Gelfoam, Surgifoam
            - Coils: 0.035" vs. 0.018", pushable vs. detachable
        - **Balloon occlusion (arterial dissection)**
            - Angioplasty balloon catheter: Diameter/length based on size of lesion
        - **Stent placement (AVF, arterial dissection)**
            - Covered stent most commonly used
            - Diameter/length base on size of lesion
        - **Pharmacomechanical thrombolysis (vessel thrombosis)**
            - Mechanical thrombolysis devices
            - Infusion catheter/sheath with pharmacologic agent

PROCEDURE

Procedure Steps

- **Percutaneous aspiration or drainage (hematoma)**
    - Exclude active bleed and rebleed potential
    - Plan path of access using either US or CT
    - Advance needle into hematoma via sterile technique
    - Aspirate hematoma
        - Consider avoiding drain placement if minimal fluid returned during aspiration
    - Place indwelling drain if needed
        - Advance 0.035" guidewire into collection via needle
        - Serially dilate tract (if needed)
        - Load catheter onto stiffening cannula and advance over guidewire into collection
        - Confirm position via fluoroscopy or CT
- **US-guided compression (PSA)**
    - Consider administration of IV analgesic or sedation (procedure can be painful)
    - Apply pressure via US probe under real-time color Doppler guidance
        - Eliminate flow through PSA while maintaining flow in parent artery
    - After 10 min, slowly release pressure and reassess for persistent flow within PSA
    - Repeat pressure application in 10-min intervals until flow is obliterated when transducer is released
- **US-guided thrombin injection (PSA)**
    - Monitor distal extremity pulse throughout procedure
        - Assistant should palpate or Doppler distal pulse
        - Immediately halt procedure if any changes occur
    - Sterilely prepare/drape target area and US probe
    - Administer 1% lidocaine local anesthetic
    - Prepare thrombin (reconstituting to 1,000 IU/mL)
    - Advance 21- or 22- gauge echogenic needle into PSA sac under US guidance
        - If polylobulated, target most superficial lobule in communication with PSA neck
        - Visualize needle tip in PSA prior to thrombin injection
        - Do not aspirate blood into syringe
    - Inject thrombin under real-time color Doppler guidance
        - Small, 0.1- to 0.2-mL increments
        - Stop after cessation of internal color Doppler flow

  - Advanced technique: Challenging case/short neck
    - Compress neck (not PSA) with US until flow within PSA halted
    - Inject 0.2-0.4 mL of thrombin into noncompressed PSA
    - Wait 30 sec prior to releasing pressure
  - Reimage 10 min after thrombin injection
    - If persistent flow, repeat thrombin injection as above
- **Embolization (hematoma, AVF, laceration)**
  - Obtain vascular access in usual fashion
  - Place sheath and introduce 4- to 5-Fr catheter
  - Select target vessel and obtain DSA images
    - Consider coaxially introduction of microcatheter via catheter
    - Negotiate microcatheter into target lesion
  - Obtain DSA images through catheter/microcatheter
    - Confirm target appropriate for embolization
    - Confirm catheter position for embolization
    - Confirm vessel safe to embolize
      - ☐ If not, consider covered stent placement to exclude bleed and maintain vessel patency
  - Deliver coils
    - Consider "sandwich" technique (deliver coils distal to bleed, then proximal to bleed)
    - Use coils slightly larger than target diameter
    - Intermittent contrast injection during coiling to verify position and assess progress
  - When coiling complete, obtain DSA before removing catheter/microcatheter to confirm embolization
- **Balloon occlusion (arterial dissection), stent placement (AVF, arterial dissection, laceration)**
  - Obtain vascular access in usual fashion
  - Introduce vascular access sheath over guidewire
  - Introduce appropriate diagnostic catheter
  - Obtain diagnostic angiogram; evaluate target lesion
  - Position selective catheter proximal to target
    - Gently advance guidewire across lesion
    - Advance selective catheter over wire
    - Inject contrast to confirm catheter tip position
    - Once tip is beyond lesion, exchange for stiff guidewire
  - Exchange for balloon angioplasty catheter
    - Base balloon size on adjacent normal vessel diameter
    - Maintain guidewire position across lesion
  - Gently inflate balloon, achieve apposition with vessel wall
    - Keep balloon inflated for several minutes
  - Deflate balloon and perform DSA without removing wire
    - Repeat prolonged balloon inflation if needed
    - Place stent if balloon occlusion fails
  - Advance stent into position and carefully deploy
  - Remove delivery system without removing guidewire
  - Inject guiding catheter/sheath or access sheath
    - Confirm satisfactory stent position/expansion
- **Thrombolysis (vessel thrombosis)**
  - Obtain vascular access in usual fashion
  - Introduce vascular access sheath over guidewire
  - Introduce appropriate diagnostic catheter
    - Obtain diagnostic angiogram; evaluate target lesion
  - Advance guidewire and catheter across thrombus
  - Perform thrombolysis
    - Catheter directed (if extensive): Position infusion catheter completely crossing thrombus and infuse thrombolytic (e.g., tPA)
    - Pharmacomechanical (if focal, or prior to catheter-directed thrombolysis): Inject 5-10 mg of tPA locally, after 15-30 min, macerate clot with balloon angioplasty or rotational device, perform thromboaspiration
  - Repeat diagnostic angiogram to determine if any additional treatment necessary

Alternative Procedures/Therapies

- Surgical
  - Hematoma: Evacuation, arterial repair
  - PSA: Primary vascular repair
  - AVF: Primary vascular repair, fistula ligation
  - Arterial dissection: Surgical bypass
  - Arterial thrombosis: Open thrombectomy, surgical bypass

OUTCOMES

Complications

- **Percutaneous aspiration or drainage**
  - Nontarget needle placement
  - Hematoma reexpansion following drainage
- **US-guided compression**
  - PSA reperfusion (2%)
  - Acute expansion &/or rupture (2%)
  - Thromboembolism (< 1%)
- **US-guided thrombin injection**
  - PSA reperfusion (2%)
  - Thromboembolism (< 1%)
  - Thrombosis of native artery during thrombin injection
- **Endovascular interventions (embolization, balloon occlusion, stenting, thrombolysis)**
  - Nontarget embolization or stenting
  - Propagation of thrombus or dissection
  - Vessel rupture

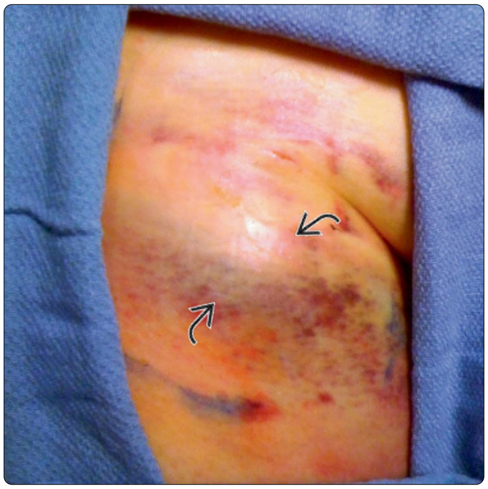
Expected Outcomes

- **US-guided compression**
  - Technical success: 63-88%
    - Increased failure with systemic anticoagulation, PSA size > 4 cm
  - Mean compression time: 30-44 min
- **US-guided thrombin injection**
  - Technical success: 93-100%
    - Increased failure with PSA size > 6 cm
  - Mean injected thrombin dose: 225-425 IU
- **Endovascular interventions (embolization, balloon occlusion, stenting, thrombolysis)**
  - Variable success rates depending on size/severity of lesions

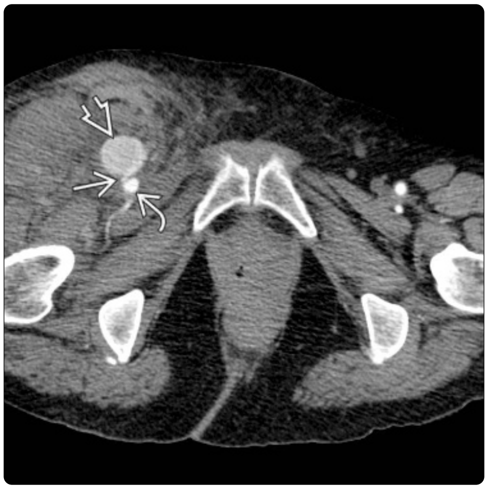
SELECTED REFERENCES

1. Gabrielli R et al: Thrombin injection and compression with removable guidewire in the treatment of postcatheterization femoral pseudoaneurysm. J Cardiovasc Surg (Torino). 57(4):510-3, 2016
2. Bechara CF et al: Access site management with vascular closure devices for percutaneous transarterial procedures. Erratum in: J Vasc Surg. 54(5):1556, 2011

PSA: Percutaneous Thrombin Treatment (Physical Exam)

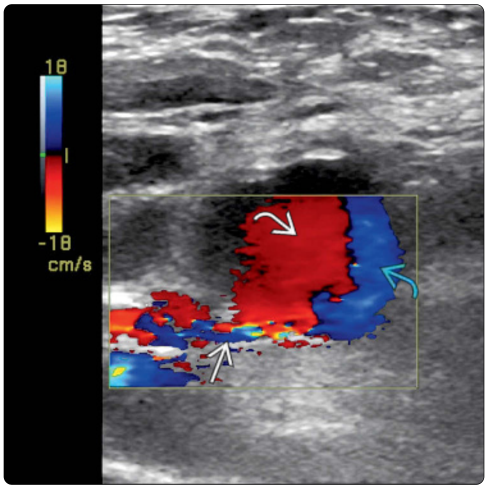


PSA: Percutaneous Thrombin Treatment (CECT)

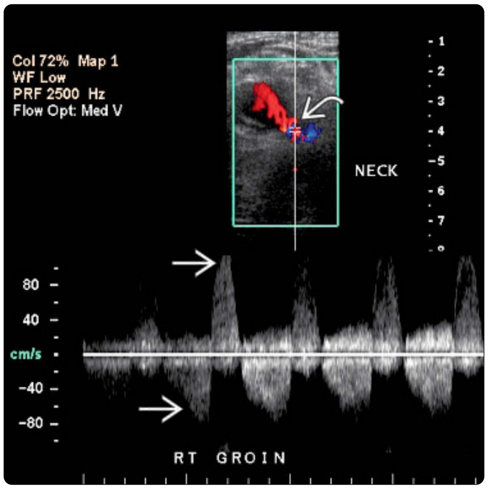


(Left) *Patient with ecchymosis and painful, pulsatile proximal thigh mass ↪ 1 day after transfemoral arterial access, suspicious for pseudoaneurysm (PSA), is shown.* **(Right)** *CECT of the same patient shows the contrast-filled PSA ⇨ and its communication → with the underlying distal common femoral artery ↪.*

PSA: Percutaneous Thrombin Treatment ("Ying-Yang")

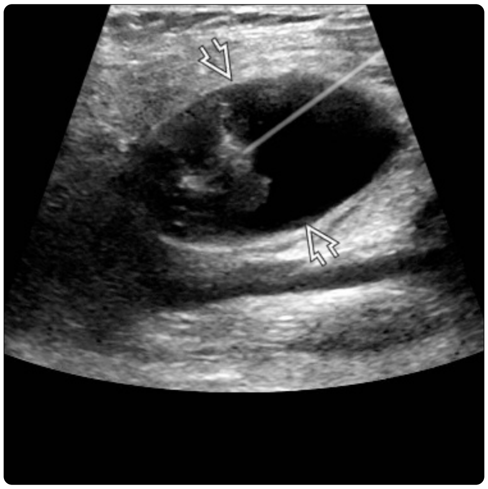


PSA: Percutaneous Thrombin Treatment (Biphasic Waveform)

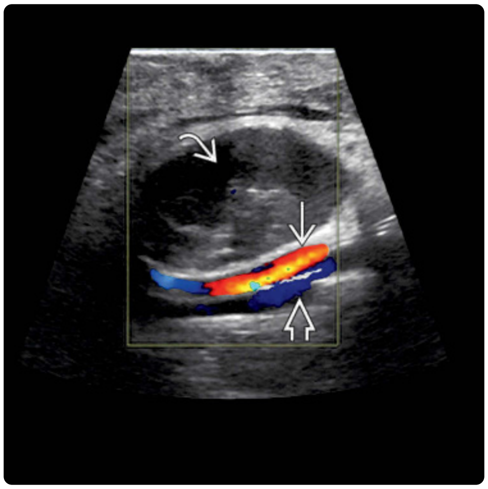


(Left) *Color Doppler US of the mass shows a round vascular structure with mixed arterial ↪ and venous ↪ signal, the so-called "yin-yang" sign, typical of a PSA. The PSA neck is also identified →.* **(Right)** *Color Doppler US of the PSA neck ↪ confirms a biphasic → arterial waveform, also a characteristic finding of PSAs.*

PSA: Percutaneous Thrombin Treatment (Percutaneous Access)

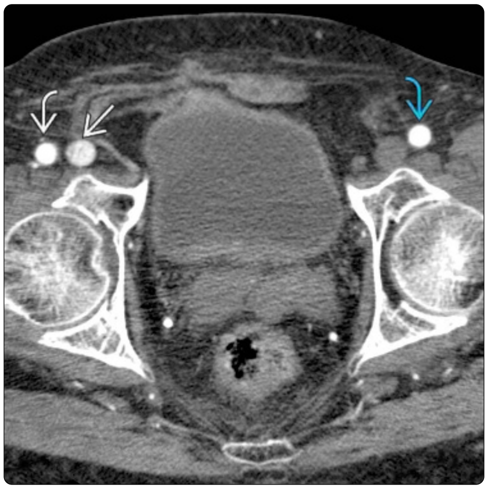


PSA: Percutaneous Thrombin Treatment (Posttreatment)

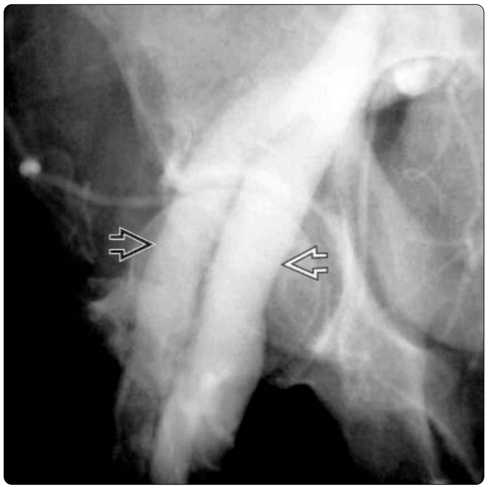


(Left) *A needle was advanced under real-time US guidance into the center of the PSA ⇨, successfully avoiding access of the PSA neck.* **(Right)** *Thrombin aliquots of 0.2 mL were injected under real-time color Doppler guidance until there was no longer any vascular signal within the PSA ↪. The underlying femoral artery → and vein ⇨ remain patent.*

Iatrogenic AVF (Diagnostic CECT)

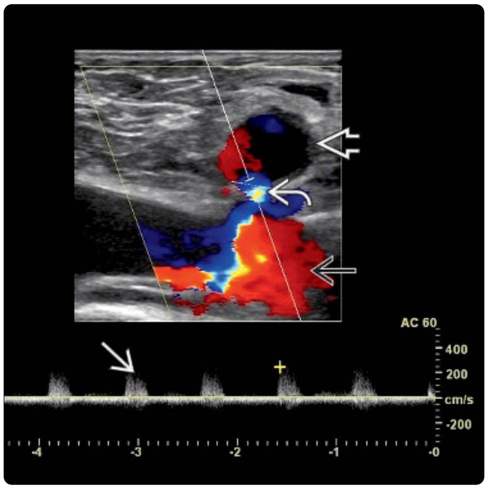


Iatrogenic AVF (Angiogram)

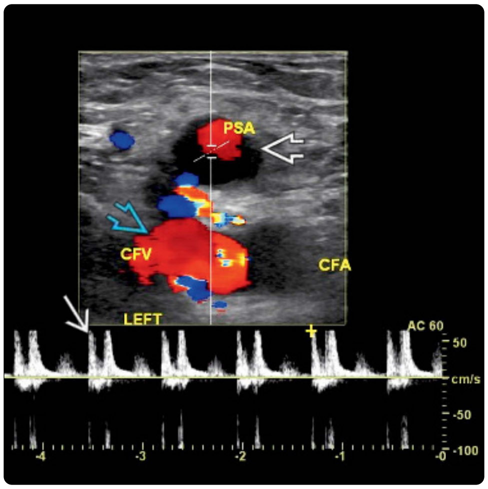


(Left) *Axial CTA in a patient with groin pain after a right transfemoral arteriogram shows abnormal simultaneous filling of the right femoral artery ↪ and vein →. Note the normal left side in which only the femoral artery ↪ is opacified.* **(Right)** *Angiogram via a catheter introduced from a left transfemoral approach and positioned in the right external iliac artery confirms an arteriovenous fistula with simultaneous filling of the right common femoral artery ⇨ and vein ⇨.*

AVF With PSA (Color Doppler US)

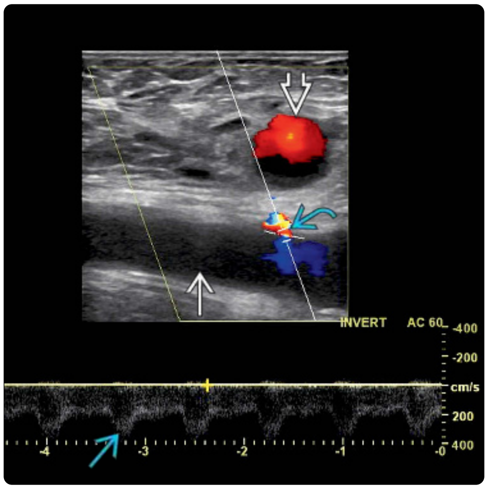


AVF With PSA (Arterial Waveform in Common Femoral Vein)

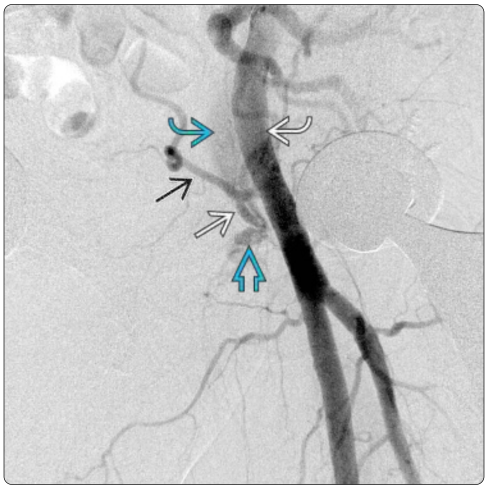


(Left) *A round vascular structure ⇨ is connected by a narrow neck ↪ to the common femoral artery → in this patient. A cursor sample in the neck shows an arterial waveform →, which is not biphasic.* **(Right)** *Color Doppler US again shows the round vascular structure ⇨, which has an arterial waveform → when sampled with a cursor. The structure is consistent with a PSA but is connected to the common femoral vein ⇨, which has an arterial color assignment in this US.*

AVF With PSA (Arterial Waveform in Venous Channel)



AVF With PSA (DSA Reveals Anatomic Variant)



(Left) *Color Doppler US with the cursor ↪ positioned at the margin of the left common femoral vein → (where there is a narrow channel coursing toward the PSA ⇨) shows an arterialized waveform →. Findings are consistent with coexistent arteriovenous fistula.* **(Right)** *A subsequent left common femoral DSA shows simultaneous filling of the artery ↪ and vein ↪. The fistula arises from a small PSA ⇨ of an accessory obturator artery → off the inferior epigastric artery →. This is an important and not uncommon anatomic variant.*

KEY FACTS

TERMINOLOGY

- **Acute aortic syndromes**: Spectrum of abnormalities that acutely compromise aortic wall integrity
  - **Thoracic aortic dissection**: Intimal tear extends into aortic wall; blood flow separates wall layers
  - **Intramural hematoma**: Hemorrhage within aortic wall without initial intimal disruption
  - **Penetrating atherosclerotic aortic ulcer**: Plaque rupture through aortic internal elastic membrane
- **Stenoses/occlusions of thoracic aorta & great vessels**: Atherosclerosis most common cause
  - Great vessel lesions often occur at/near origins
  - Severe stenoses may progress to chronic occlusion
- **Thoracic aortic aneurysm**: Aortic dilatation exceeding normal diameter by > 50%

PROCEDURE

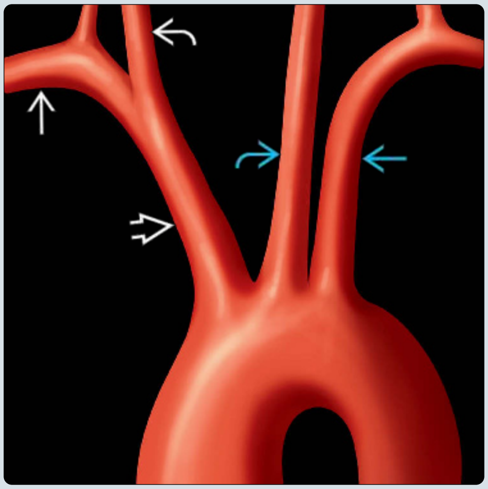
- **Great vessel lesions**: Femoral vs. retrograde brachial access dependent on location & type of intervention
  - May occasionally require combined arterial access; useful for crossing chronic total occlusions
  - Consider introducing guiding sheath/catheter
  - After obtaining DSA, determine if transcatheter therapy appropriate, if intervention can be performed without jeopardizing critical branches
  - Angioplasty/stenting widely accepted treatment for intrathoracic great vessel lesions when feasible

OUTCOMES

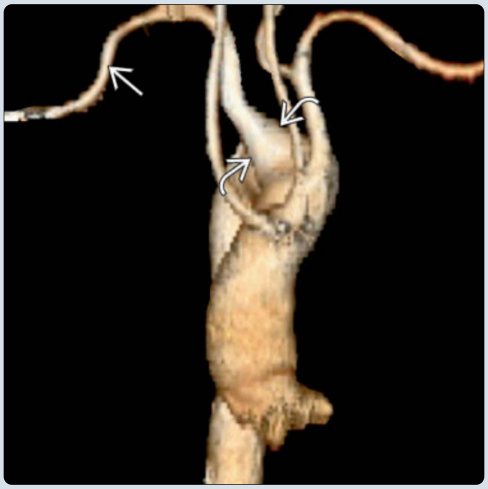
- Endovascular treatment preferred for most lesions
  - Surgery reserved for endovascular failure or lesions inappropriate for endovascular treatment

(Left) *The brachiocephalic artery ⇨ is the 1st aortic branch & divides into the right common carotid ↪ & subclavian → arteries, whereas the left common carotid ↪ & subclavian → arteries arise directly from the aortic arch.* **(Right)** *CT reconstruction shows the typical appearance of an aberrant right subclavian artery → with an associated diverticulum of Kommerell ↪.*

Typical Aortic Arch

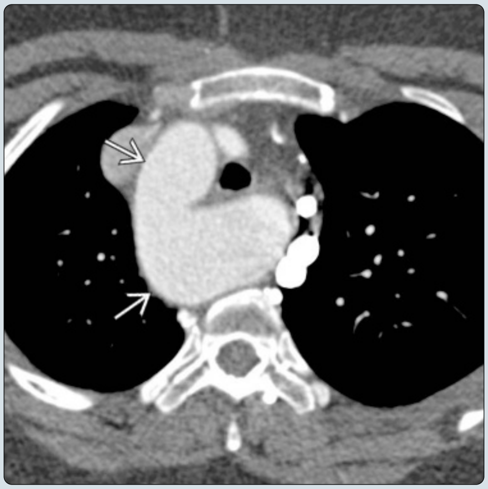


Variant Anatomy: Aberrant Right Subclavian & Diverticulum of Kommerell

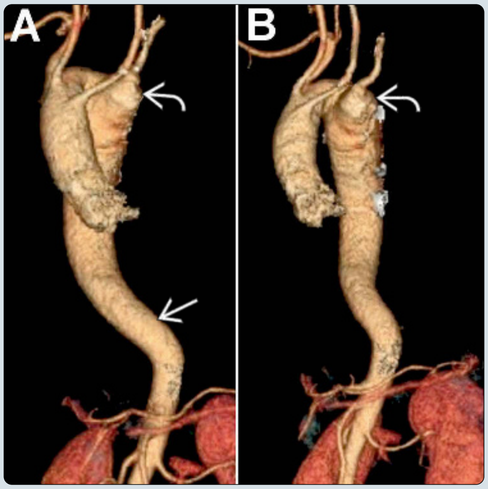


(Left) *The most common type of right aortic arch → has an associated aberrant left subclavian artery. There may be an accompanying diverticulum of Kommerell. This form of right aortic arch has a low incidence of associated congenital heart disease.* **(Right)** *(A) Anteroposterior & (B) oblique CT reconstructions of a right aortic arch with aberrant left subclavian artery show a small diverticulum of Kommerell ↪. Although the arch is right-sided, the aorta descends on the left →.*

Variant Anatomy: Right Aortic Arch With Aberrant Left Subclavian Artery



Variant Anatomy: Right Aortic Arch With Aberrant Left Subclavian Artery



TERMINOLOGY

Definitions

- **Acute aortic syndromes**: Spectrum of abnormalities that acutely compromise aortic wall integrity
  - **Thoracic aortic dissection (AD)**: Intimal tear extends into aortic wall; blood flows between/separates wall layers
    - Blood flow separates aortic wall structures, producing "true" & "false" lumina
      - Aortic branch vessel perfusion may be compromised; end-organ ischemia may result
    - Weakened aortic wall may rupture; high mortality
      - Chronic dissection may progress to aneurysm
  - **Intramural hematoma (IMH)**: Hemorrhage within aortic wall media without initial intimal disruption
    - May occur as 1° event in hypertensive patients
      - Spontaneous bleeding from vasa vasorum into aortic media causing hematoma formation
    - May result from penetrating atherosclerotic ulcer (PAU)
    - Intramural hematoma weakens aortic wall
      - May spontaneously progress to aortic dissection if intimal layer ruptures ("entry tear")
      - Increased risk of aortic rupture
      - Association with ulcer-like projection in arch or ascending aorta indicative of intimal disruption
    - May resolve over time, persist, or evolve into aneurysm or PAU
    - Prognosis worsens if associated with ulcer-like projection, IMH > 2 cm thick, aortic diameter > 5 cm, or pleural or pericardial effusion
  - **PAU**: Plaque rupture through aortic internal elastic membrane
    - Often in patients with extensive intimal calcifications & atherosclerotic plaques
    - Ulcer/hematoma weakens aortic wall
      - May progress to aortic dissection
      - May form saccular pseudoaneurysm
      - Increased risk of acute rupture
    - May be single or multiple
    - Often with associated intramural hematoma
- **Thoracic aortic aneurysm (TAA)**: Aortic dilatation exceeding normal diameter by > 50%
  - Various etiologies
    - **Degenerative**: Commonly due to atherosclerosis
      - Abnormal matrix metalloproteinase activity
      - Etiology in 75% of thoracic aortic aneurysms
    - **Connective tissue disorders**: Genetic conditions associated with acute aortic syndromes/aneurysms
      - **Ehlers-Danlos syndrome**: Type IV vascular subgroup characterized by generalized vascular fragility; frequent arterial ruptures
      - **Loeys-Dietz syndrome**: Phenotypically similar to Ehlers-Danlos type IV subgroup
      - **Marfan syndrome**: Cystic medial degeneration; usually involves aortic root (annuloaortic ectasia)
      - **Cystic medial necrosis**
    - **Infection (mycotic)**: Localized infection weakens/compromises integrity of aortic wall
      - Typically saccular configuration
    - **Pseudoaneurysm**: Disruption of 1 or more arterial wall layers; forms contained rupture
      - May be due to aortic injury following penetrating or blunt trauma (e.g., deceleration injury)
      - Also associated with infectious, inflammatory, & neoplastic disease
  - Increased rupture risk if TAA > 5 cm diameter or growth of > 1-cm per year
    - Rupture risk doubles per 1 cm aneurysm increment
  - **Great vessel aneurysms**: Account for only 1-3% of all arterial aneurysms
    - Brachiocephalic artery most commonly involved
      - Same etiologies as thoracic aortic aneurysms
- **Stenoses/occlusions of thoracic aorta & great vessels**
  - **Atherosclerosis**: Most common cause
    - Severe stenoses may progress to chronic occlusion
    - Often occur at/near origins from thoracic aorta
  - **Coarctation**: Congenital condition in which thoracic aorta narrows in region where ductus arteriosus inserts; 3 subtypes
    - **Preductal**: Occurs proximal to ductus arteriosus
      - Due to decreased left heart blood flow from fetal cardiac anomaly; leads to hypoplastic aorta
      - Aortic perfusion distal to narrowing relies on ductus arteriosus; can be life-threatening if severe
      - Occurs in ~ 5% of infants with Turner syndrome
    - **Ductal**: Narrowing at ductus arteriosus insertion
      - Usually appears when ductus arteriosus closes
    - **Postductal**: Narrowing distal to ductus arteriosus
      - Likely due to contraction & fibrosis of ductus arteriosus at birth, subsequently narrowing aorta
      - Most common type in adults
  - **Pseudocoarctation**: Rare congenital anomaly in which kinking/buckling of thoracic aorta occurs; resembles true thoracic coarctation on imaging
    - Involves descending thoracic aorta immediately distal to left subclavian artery origin
    - Differentiated from true coarctation by absence of significant hemodynamic obstruction
  - **Subclavian steal syndrome**: Retrograde flow in vertebral &/or internal mammary artery due to proximal subclavian artery stenosis or occlusion
    - Can cause posterior fossa ischemia resulting in ataxia, dizziness
    - May also present with arm claudication
- **Vasculitis**
  - **Giant cell arteritis (GCA)**: Vasculitis affecting medium to large-caliber arteries; similar to Takayasu arteritis & may represent single disease spectrum
    - Age at onset often used to classify patients
      - GCA affects older population (> 50 years)
      - Classically involves temporal arteries &/or cervical carotid arteries
    - 20-30% of patients with GCA have involvement of aorta & primary branches
      - May cause long stenoses of mid/distal subclavian arteries, extending into axillary arteries; seen more frequently in GCA than in Takayasu
    - Diagnosis confirmed by arterial biopsy
      - Typically biopsy of temporal artery; easily accessible & usually involved when disease present

      - ☐ Mononuclear cell infiltration/granulomatous inflammation with multinucleated giant cells
  - ○ **Takayasu arteritis**: Large vessel granulomatous inflammatory vasculitis
    - – Affects people younger than 40 years
      - ☐ Often occurs between 15-30 years
    - – Classically characterized by 3 stages
      - ☐ Active inflammation; constitutional symptoms
      - ☐ Vascular inflammation; vessel pain/tenderness
      - ☐ Vascular fibrosis or degeneration causing ischemia or aneurysms
    - – Involves thoracoabdominal aorta &/or primary branches, pulmonary arteries

Pertinent Vascular Anatomy

- **Brachiocephalic (innominate) artery**: 1st branch of thoracic aorta; divides into right common carotid & right subclavian arteries
  - ○ **Right common carotid artery**: Supplies face & right cerebral hemisphere; divides into external & internal carotid arteries
  - ○ **Right subclavian artery**: Supplies right arm with some branches to head & thorax; becomes axillary artery at lateral margin of 1st rib
    - – **Vertebral artery**: Supplies cerebellum
    - – **Internal mammary artery**: Yields anterior intercostals, breast perforators; terminates as superior epigastric & musculophrenic arteries
    - – **Costocervical trunk**: Divides into supreme intercostal & deep cervical arteries
    - – **Thyrocervical trunk**: Divides into inferior thyroid, suprascapular & transverse cervical arteries
    - – **Dorsal scapular artery**: Supplies levator scapulae, rhomboid & trapezius muscles
- **Left common carotid artery**: 2nd branch of thoracic aorta; divides into external & internal carotid arteries
- **Left subclavian artery**: 3rd branch of thoracic aorta; yields same branches as right subclavian artery

Significant Variant Vascular Anatomy

- **Aberrant right subclavian artery**: Arises as last branch of aortic arch; most common clinically significant aortic arch malformation (0.4-2.3% incidence)
  - ○ Usually passes posterior to trachea & esophagus
    - – Patients rarely symptomatic; can cause stridor &/or swallowing difficulties (dysphagia lusoria)
  - ○ **Diverticulum of Kommerell**: Conical dilatation of aberrant right subclavian artery origin
    - – Represents distal remnant of right aortic arch
    - – Large diverticulum can be symptomatic
      - ☐ 19% present with rupture
      - ☐ Can also present with distal embolization
- **Right aortic arch**
  - ○ **With aberrant left subclavian artery**: Most common type of right aortic arch (0.1% incidence)
    - – Arch courses over right mainstem bronchus but may descend on either side of spine; left subclavian artery is last aortic branch
    - – Associated with diverticulum of Kommerell
    - – Associated congenital heart disease in 5-10%
      - ☐ Tetralogy of Fallot (71%)
      - ☐ Atrial or ventricular septal defect (21%)
      - ☐ Aortic coarctation rarely (7%)
  - ○ **With mirror-image branching**: Descending aorta almost always courses to right of spine
    - – Left innominate artery followed by right carotid & right subclavian arteries; no retroesophageal vessel
    - – Associated congenital heart disease in 90-95%
      - ☐ Tetralogy of Fallot (90%)
      - ☐ Truncus arteriosis (6%)
      - ☐ Tricuspid atresia (5%)
- **Double aortic arch**
  - ○ Most common vascular ring
    - – Aortic arches pass on both sides of trachea, join posterior to esophagus
      - ☐ Right arch larger & higher, supplies right subclavian & common carotid arteries
      - ☐ Smaller & lower left aortic arch supplies left subclavian & common carotid arteries
  - ○ Rarely associated with congenital heart disease
    - – Clinical symptoms of dysphagia &/or stridor
- **Cervical aortic arch**
  - ○ Rare anomaly; usually asymptomatic
    - – May present as pulsating supraclavicular mass
    - – May rarely produce vascular ring, compress airway
  - ○ Right-sided location in over 80%
    - – Branching may be normal or mirror image

PREPROCEDURE

Indications

- **Thoracic aortic aneurysm**
  - ○ Typically requires repair when diameter exceeds 5.5 cm or if patient symptomatic
    - – Thoracic endovascular aortic repair (TEVAR) preferred treatment modality when appropriate
- **Thoracic aortic dissection**
  - ○ 2 classification schemes based on aortic distribution
    - – Stanford classification (most commonly used)
      - ☐ Stanford A: Dissection involves ascending aorta
      - ☐ Stanford B: Ascending aorta not involved; dissection commences distal to left subclavian artery
    - – DeBakey classification
      - ☐ DeBakey I: Entire thoracic aorta (ascending/descending) involved, ± abdominal aorta
      - ☐ DeBakey II: Originates in & confined to ascending aorta, up to innominate artery
      - ☐ DeBakey III: Originates in descending aorta; extends distally & may include abdominal aorta
  - ○ Stanford A & DeBakey I & II dissections typically require surgical or endovascular intervention
    - – Graft insertion with concurrent aortic valve replacement when necessary
  - ○ Stanford B & DeBakey III dissections managed medically unless complications occur
    - – Compromised arterial perfusion due to compressed true aortic lumen; resultant ischemia
      - ☐ Restore arterial perfusion to ischemic vascular territories/end organs
    - – Rupture or aneurysmal degeneration
- **Traumatic aortic or great vessel injury**

  - Penetrating/blunt aortic or great vessel trauma resulting in disruption, pseudoaneurysm or transection
    - TEVAR preferred treatment when appropriate
- **Intramural hematoma**
  - May progress to AD; worse prognosis if associated with penetrating ulcer or ulcer-like projection
  - Type B often managed medically by aggressive blood pressure reduction using β-blockers; consider intervention if progresses to dissection
  - Mortality of type A similar to AD, & treatment often surgical
    - 40% inpatient mortality with medical management only of type A IMH
  - More likely to develop periaortic hematoma & pericardial effusion vs. AD
- **PAU**
  - Increased ulcer depth & diameter predicts disease progression; significant aortic wall weakening
    - Can lead to dissection, pseudoaneurysm, & rupture
    - Consider endovascular or surgical intervention
  - Increased rupture rate if symptomatic (38%)
    - Intervention for refractory/recurrent symptoms
- **Great vessel stenotic/occlusive disease**
  - Chronic limb ischemia from stenoses/occlusions
    - May present as upper extremity claudication, rest pain, ulceration, gangrene
  - Subclavian steal syndrome symptomatology
    - Angioplasty & stenting widely accepted treatment for this & other intrathoracic great vessel lesions

Contraindications

- **General**
  - Uncorrectable coagulopathy
  - Severe renal insufficiency
    - Nondialysis dependent
  - History of severe contrast allergy/anaphylaxis
  - Systemic infection
    - Risk of infection of covered stent (rare)
- **Acute aortic syndromes**
  - Asymptomatic aortic dissection, intramural hematoma, penetrating atherosclerotic ulcer not involving ascending aorta
    - May be medically managed; requires close clinical & imaging surveillance to assess for progression
- **TAA**
  - Poor aneurysm anatomy/morphology for TEVAR
- **Thoracic aorta & great vessel vasculitis/inflammation**
  - Evidence of active disease
    - Systemic symptoms
      - Fever, arthralgia, myalgia
    - Laboratory abnormalities
      - Elevated erythrocyte sedimentation rate
      - Positive C-reactive protein
    - May adversely affect revascularization
- **Great vessel stenotic/occlusive disease**
  - Relative contraindication to stent placement across lesion crossing or involving thoracic outlet
    - Higher likelihood of stent compression & fracture
    - May need surgical decompression or vascular bypass
  - High-risk lesions for causing embolic complications
    - Mobile thrombus attached to plaque
    - Fresh thrombosis (< 1 month) causing occlusion
      - May consider preintervention thrombolysis or anticoagulation for 2-4 weeks

Preprocedure Imaging

- CTA
  - Excellent delineation of arterial anatomy/pathology
    - Characterization of target lesion(s)
    - Preprocedure thoracic aortic endograft planning
    - Preferred right-sided injection to minimize artifact in aorta from contrast bolus
  - Precontrast phase helpful for IMH
- MRA
  - Excellent delineation of arterial anatomy & pathology
    - Useful in acute, inflammatory & infectious processes
- DSA
  - Somewhat limited role in preprocedure evaluation
    - Primary imaging guidance during intervention

Getting Started

- Things to check
  - Clinical history & physical examination
    - Appropriate procedure indications
    - Comprehensive vascular evaluation
      - Detailed pulse examination/Doppler evaluation
      - Obtain preprocedure baseline upper extremity pulses on affected side
    - Review prior endovascular & surgical interventions
      - May influence choice of optimal access
    - Current medications
      - Any anticoagulants, antiplatelet agents, oral hypoglycemic agents, antihypertensives
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - Complete blood count
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ratio ≤ 1.5
      - Normal prothrombin time, partial thromboplastin time
    - Inflammatory markers
      - C-reactive protein
      - Erythrocyte sedimentation rate
  - Limit oral intake: NPO for 8° prior to procedure
    - If moderate sedation or general anesthesia planned
    - Take any oral medications with sip of water
- Medications
  - Agents for moderate sedation
    - Fentanyl
    - Midazolam
  - Heparin
    - Various intraprocedural administration regimens
      - Bolus dose of 2,500-5,000 U; followed by infusion of 1,000 U/h
      - Loading dose of 50-100 U/kg; followed by continuous infusion of 15-25 U/kg/h
  - Vasodilator

    - Typical bolus dose of 100 µg nitroglycerin
    - Prevents/treats catheter-induced vasospasm
  - Clopidogrel
    - May electively give loading dose before procedures involving stenotic & occlusive disease
      - 300 mg is minimum loading dose
    - Continue maintenance dose post procedure
      - 75-mg daily dose for 4-6 weeks minimum
- Equipment list
  - Arterial access equipment
    - Micropuncture access kit
      - Micropuncture needle & microwire
      - Transitional dilator
  - Catheters/sheaths
    - Vascular access sheath
      - Permits catheter exchanges as necessary; reduces local complications at access site
      - Various available sheath sizes; choice depends on catheter & device used for procedure
    - Diagnostic catheter
      - Flush catheter (e.g., pigtail, Omni Flush)
      - Selective catheter (e.g., Davis, Simmons)
    - Angioplasty (PTA) balloon catheter
      - Various sizes, configurations
  - Guidewires
    - 0.035" guidewire
    - Angled or straight-tipped hydrophilic guidewire
      - Useful for crossing stenosis/occlusion
      - Useful for selective arterial catheterization
    - 0.014-0.018" microwire
      - For use with microcatheters; rapid-exchange stents/angioplasty balloons
    - Stiff guidewire
      - e.g., Amplatz, Lunderquist, Rosen
      - Provides stability when advancing devices
  - Stents
    - Aortic endografts for TEVAR
    - Covered
      - Balloon mounted: Allows precise placement in great vessels; limited by available lengths; greater radial force but susceptible to mechanical compression
      - Self-expanding: More flexible design than balloon mounted; longer lengths available
    - Noncovered
      - Balloon mounted: More precise placement
      - Self-expanding: Preferred for carotid artery stenting; also useful in other great vessels

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Typically common femoral artery access used
  - May consider ipsilateral upper extremity access
    - Retrograde brachial artery access
  - Antegrade femoral vs. retrograde brachial access dependent on lesion location/type of intervention
    - May occasionally require combined arterial access
      - e.g., both femoral & brachial artery access

Procedure Steps

- **General**
  - Sterilely prepare & drape intended access site
  - Administer local anesthetic
  - Obtain arterial access; introduce access sheath
  - Choose appropriate diagnostic catheter
    - Use flush catheter for thoracic aortogram (e.g., pigtail, Omni Flush catheter)
    - Use selective catheter for brachiocephalic/left carotid/left subclavian artery (e.g., Davis, Simmons catheter)
  - Introduce diagnostic catheter over guidewire
  - Use double-flush technique at ascending aorta & great vessels
    - Withdraw blood from catheter from 1st syringe, discard
    - Withdraw blood & inject saline flush with 2nd syringe
    - Ensure no air bubbles in catheters & syringes
      - Air bubbles can embolize through carotid & vertebral arteries, resulting in cerebrovascular accident
  - Position catheter appropriately for DSA
    - Place flush catheter proximal to brachiocephalic origin to evaluate ascending thoracic aorta & arch
    - Selective catheter in appropriate target artery
      - Place catheter proximal to target arterial segment
      - Unless contraindicated, consider intraprocedural heparinization, given small arterial calibers
  - Obtain DSA images
    - 1st, hand inject contrast to ensure proper catheter position & exclude potential injection into small branch arteries (risk of rupture with power injection)
    - Optimal position for evaluating aortic arch/great vessel origins: 30-45° left anterior oblique
    - Typical thoracic arteriogram contrast injection parameters
      - Aorta: 20 mL/s flow rate; 40 mL vol
      - Subclavian (distal to cephalics): 6-8 mL/s flow rate; 15 mL vol
  - Analyze DSA images
    - Identify/confirm abnormality
      - Evaluate lesion characteristics
    - Determine if transcatheter therapy appropriate
      - Assess whether intervention can be performed safely without jeopardizing critical branches
    - Determine if additional/alternate access needed
  - Proceed to intervention if appropriate
    - Document results with DSA after intervention
  - Remove catheters & sheaths; obtain hemostasis
- **Transcatheter intervention in great vessels (general)**
  - Consider introducing guiding sheath/catheter
    - Position sheath proximally (near lesion)
      - Facilitates coaxial introduction of devices/stents
      - Allows contrast injection during intervention
  - May consider retrograde brachial access
    - Dependent upon location of lesion
    - Brachial artery susceptible to access-related iatrogenic arterial injury, thrombosis
      - Due to small arterial caliber, vasospasm possible

    - Consider combined approach for difficult/complex arterial lesions (e.g., origin occlusions)
        - Consider access from brachial & femoral arteries
            - May facilitate access to lesion via catheters from both central & peripheral approaches
- **Chronic total occlusion revascularization**
    - **Antegrade recanalization via femoral approach**
        - Place access sheath near origin of vessel from aorta
        - Cannulate vessel origin with diagnostic catheter
        - Use diagnostic catheter & guidewire combination to cross lesion; position guidewire distal to lesion
            - Advance catheter over guidewire beyond lesion
            - Obtain DSA; confirm intraluminal position
        - Exchange for stiff guidewire
        - Perform angioplasty of lesion prior to stenting
    - **Antegrade-retrograde (combined) recanalization**
        - Obtain brachial access; place short access sheath
        - Use diagnostic catheter & guidewire combination to cross lesion from brachial access
        - Advance catheter over guidewire beyond lesion
            - Place exchange length guidewire via catheter
        - Introduce long access sheath via femoral artery; position tip near target vessel origin from aorta
            - Introduce snare catheter through sheath
        - Advance exchange length guidewire into aorta
            - Use snare catheter to ensnare guidewire tip
        - Withdraw guidewire from long sheath using snare
        - Introduce catheter over snared guidewire via femoral access sheath; advance across lesion
        - Place new guidewire via transfemoral catheter
        - Use femoral access for subsequent PTA/stenting
            - Large devices safer via femoral vs. brachial access
- **Great vessel aneurysm exclusion**
    - Requires placement of covered stent across aneurysm
    - Choose appropriate covered stent for exclusion
        - Oversize stent diameter by ~ 20%
            - Relative to proximal/distal attachment sites
        - Stent ends should terminate in nonaneurysmal, disease-free arterial segments
            - Need ~ 1 cm length proximal/distal seal zones
        - Ensure stent will not exclude critical branches

Alternative Procedures/Therapies

- Surgical
    - Surgical repair/revascularization (e.g., carotid-subclavian bypass)

OUTCOMES

Complications

- Most feared complication(s)
    - Great vessel interventions
        - Arterial dissection, thrombosis, distal embolization
        - Stroke (3.6% incidence)
- Immediate/periprocedural complication(s)
    - Access site related
        - Groin hematoma (3%), pseudoaneurysm (1%), arteriovenous fistula (0.2%)
    - Contrast-induced nephropathy
    - Allergic/anaphylactic reaction to contrast
- Delayed complication(s)
    - In-stent stenosis, occlusion, or thrombosis
        - Most frequently due to intimal hyperplasia
        - Thrombotic occlusion may also be mechanical
    - Endoleak after covered stent placement
        - Type I or III endoleak typically associated with treatment of great vessel aneurysms

Expected Outcomes

- Treatment of great vessel stenotic/occlusive disease
    - Almost 100% technical success with stenoses; 60-100% with chronic total occlusions
    - 1-year patency: 91-100%; 5-year patency: 77%

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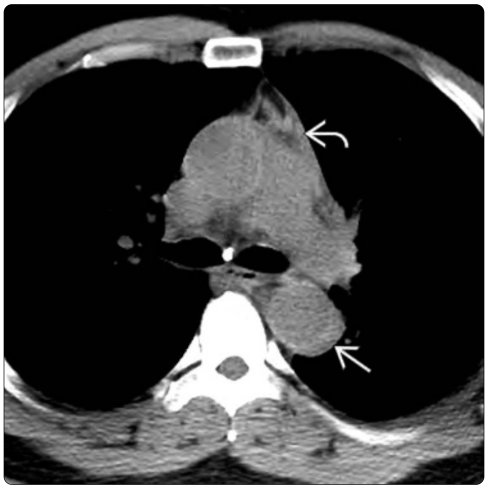
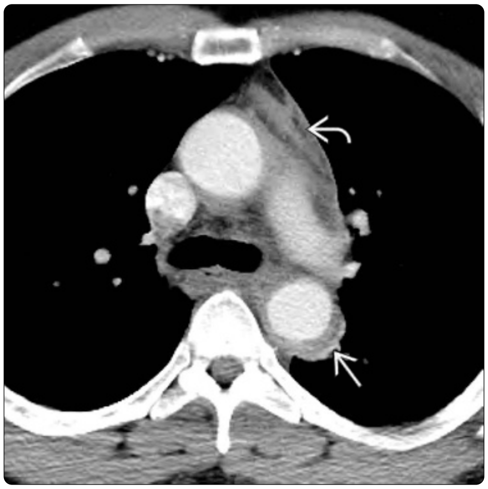
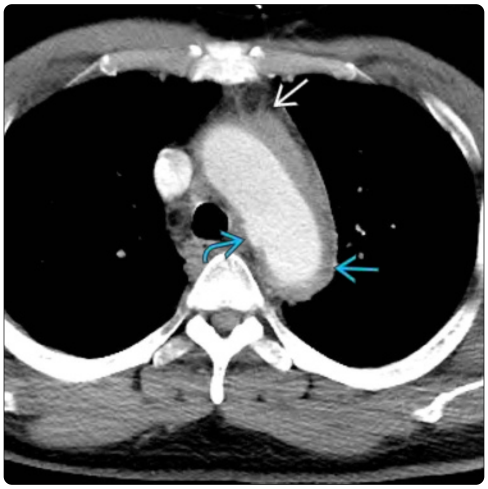
11. Sueyoshi E et al: New development of an ulcerlike projection in aortic intramural hematoma: CT evaluation. Radiology 224: 536-41, 2002

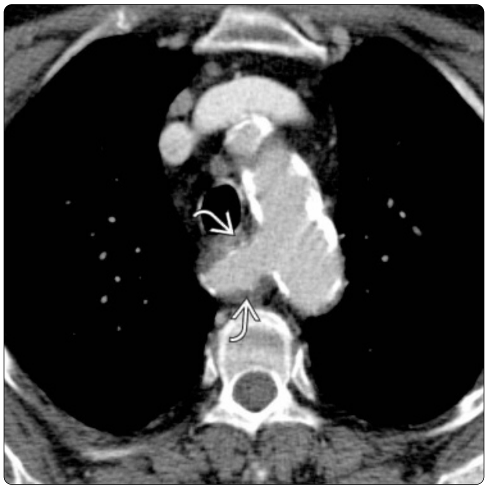
(Left) *Hyperdense hemorrhage in the descending aortic media* → *is consistent with an intramural hematoma in this 46-year-old patient with hypertension & sudden-onset chest pain. Small amount of hemorrhage in the anterior mediastinum is partially visualized* ↪*, consistent with rupture.* **(Right)** *Axial CECT in the same patient shows eccentric fluid in the descending aortic wall* →*, consistent with intramural hematoma. Small amount of hemorrhage is noted in the anterior mediastinum* ↪.


Intramural Hematoma With Rupture

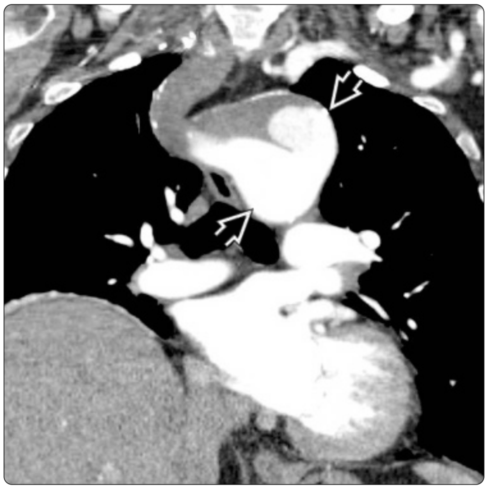

Intramural Hematoma With Rupture

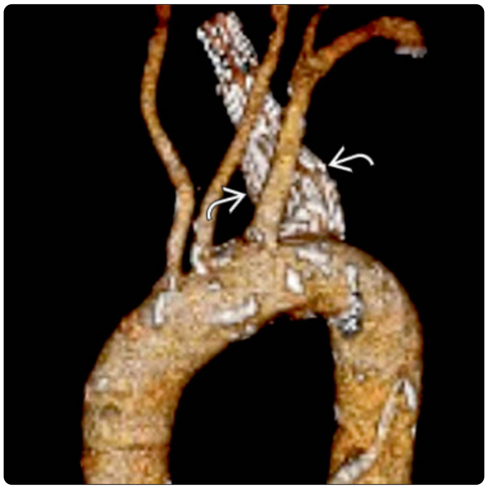
(Left) *A spontaneous intramural hematoma* → *of the aortic arch with associated ulcer-like projection* ↪ *increases risk of aortic rupture. A small amount of periaortic hematoma* → *is partially visualized in the anterior mediastinum.* **(Right)** *Conical dilatation of the aberrant right subclavian artery origin is termed a diverticulum of Kommerell. The aberrant artery* ↪ *usually courses posterior to the trachea & esophagus & may compress these structures.*


Intramural Hematoma With Periaortic Hematoma

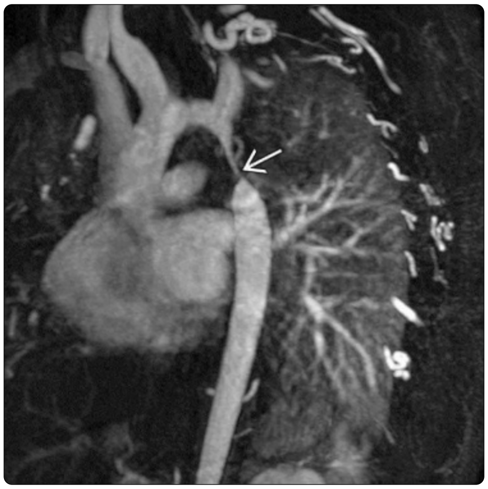

Variant Anatomy: Diverticulum of Kommerell

(Left) *Although often benign findings, an aberrant right subclavian artery & diverticulum of Kommerell can be symptomatic. The diverticulum may become aneurysmal* ⇨*, as on this CTA, with the attendant risk of rupture &/or distal thromboembolism.* **(Right)** *19% of diverticulum of Kommerell aneurysms present with rupture & an associated very high mortality rate. When identified, these aneurysms should be either surgically resected or repaired with a stent-graft* ↪*, as in this case.*

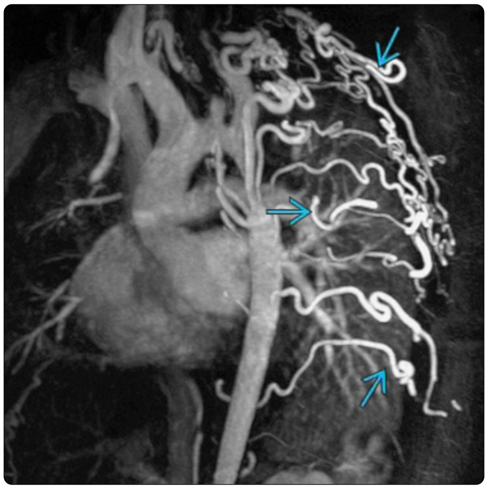

Diverticulum of Kommerell Aneurysm (Preoperative Evaluation With CTA)


Diverticulum of Kommerell Aneurysm (Endovascular Aneurysm Repair)

Coarctation of Thoracic Aorta (MRA Demonstration of Stenosis)

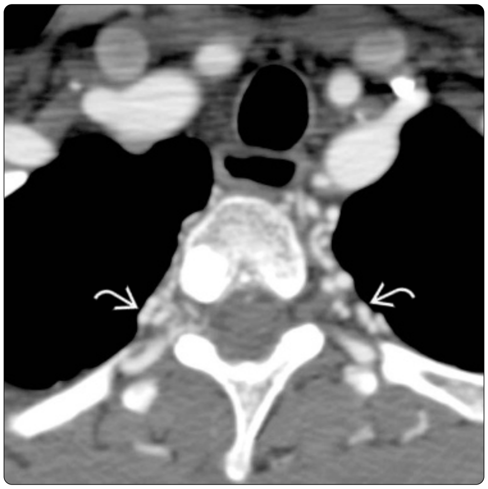


Coarctation of Thoracic Aorta (MRA Demonstration of Collaterals)

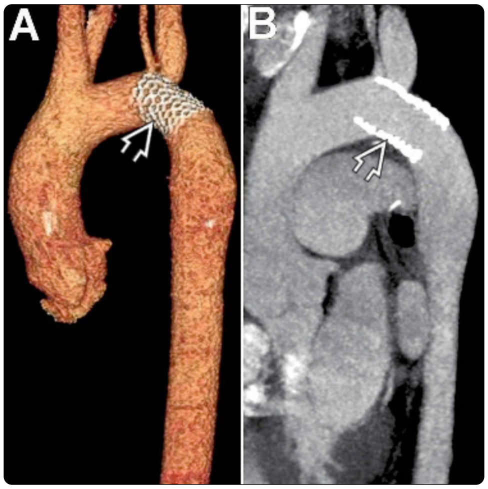


(Left) *Thoracic coarctation is a congenital condition in which the aorta narrows in the region of the ductus arteriosus insertion. In postductal coarctation, the most common type in adults, the stenosis ➔ is distal to the ductus arteriosus, as on this MRA.* **(Right)** *While mild coarctations may be asymptomatic, significant stenoses cause upper extremity hypertension & decreased lower extremity blood pressure. In adults with untreated coarctation, the lower body is perfused via extensive collaterals, such as the intercostal arteries ➔.*

Coarctation of Thoracic Aorta (CTA Demonstration of Collaterals)

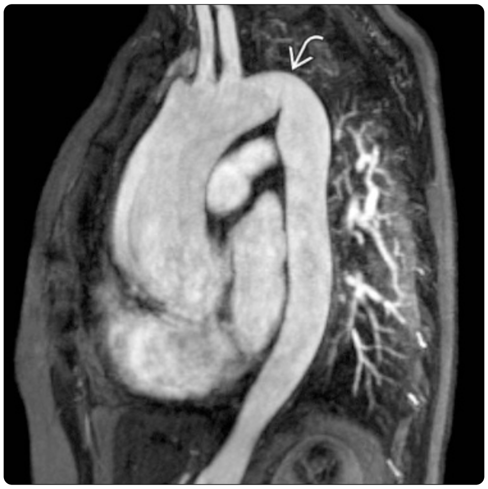


Coarctation of Thoracic Aorta (Imaging After Endovascular Repair)

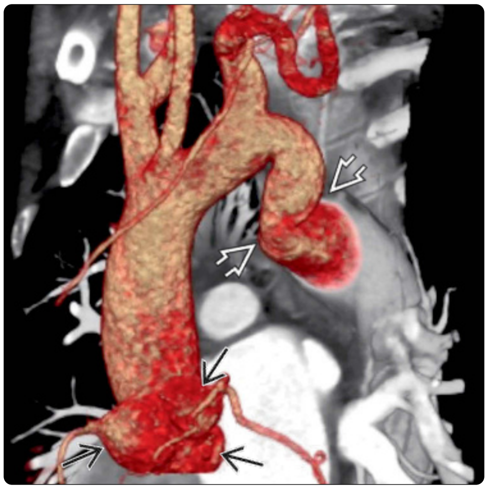


(Left) *Axial CECT in another case of postductal coarctation shows extensive arterial collaterals ➦. If untreated, coarctation can result in left ventricular hypertrophy.* **(Right)** *Treatment is conservative in asymptomatic cases, but surgical or endovascular repair may be needed in symptomatic ones. (A) 3D reformation & (B) CTA reconstruction images after angioplasty & stenting ⇨ show a patent aortic lumen.*

Thoracic Pseudocoarctation (MRA)



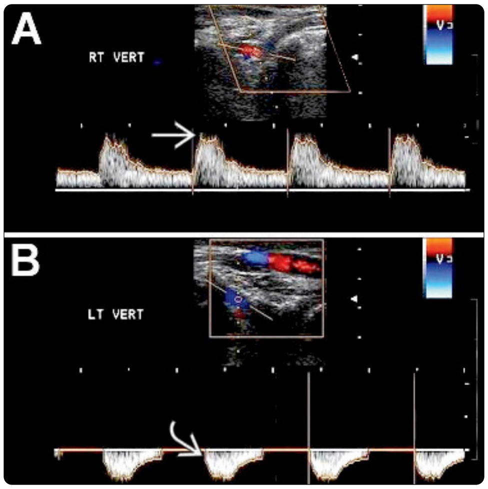
Thoracic Pseudocoarctation (CECT)



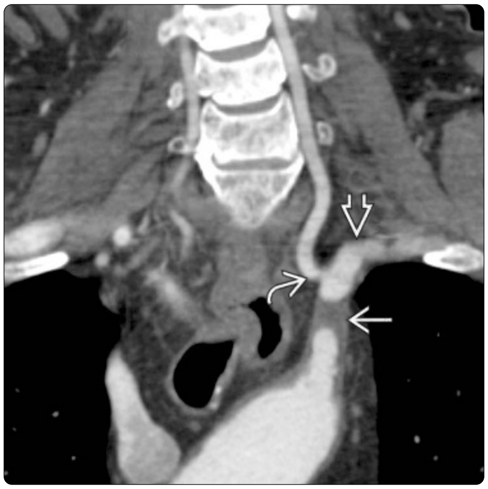
(Left) *Pseudocoarctation consists of elongation & kinking of the aortic arch. As seen on this MRA, the kinking ➦ may be mild.* **(Right)** *3D CECT shows marked kinking ⇨ of a tortuous descending aorta beyond the left subclavian artery, which is typical of pseudocoarctation. This may resemble true coarctation on imaging & is differentiated by absence of a hemodynamically significant gradient & a lack of collaterals. While a bicuspid aortic valve can occur in this entity, this one is tricuspid ➔.*

(Left) *A man with left arm claudication & ataxia was initially evaluated with US. Color Doppler US of (A) the right vertebral artery demonstrates antegrade arterial flow → while (B) there is reversal of flow ↪ in the left vertebral artery.* **(Right)** *CT reconstruction confirms a short segmental occlusion → of the left subclavian artery proximal to the left vertebral artery origin ↪. The left subclavian arterial segment ⇨ distal to the occlusion is thus dependent upon the left vertebral artery for perfusion.*

Subclavian Steal Syndrome (Vertebral Artery Color Doppler US)

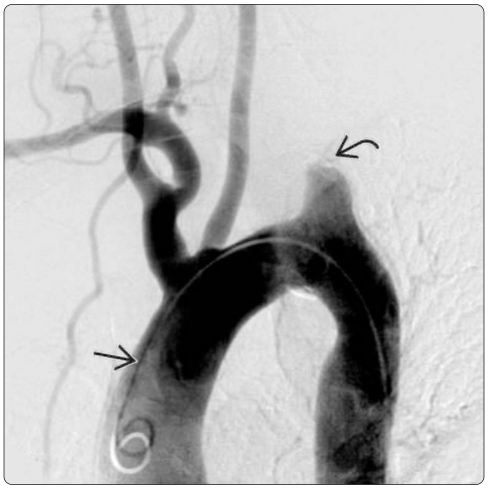


Subclavian Steal Syndrome (Evaluation for Occlusion/Stenosis)

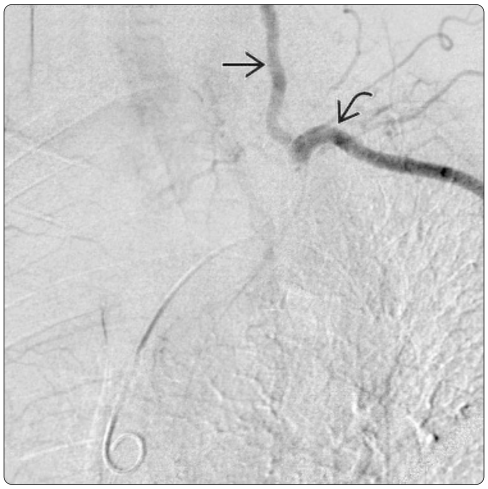


(Left) *The patient underwent angiography in preparation for endovascular treatment of the subclavian artery occlusion. DSA shows a pigtail catheter → in the ascending thoracic aorta & proximal left subclavian artery occlusion ↪.* **(Right)** *Delayed image from the thoracic aorta DSA shows retrograde flow in the left vertebral artery → with reconstitution of the distal left subclavian artery ↪. This is the classic angiographic appearance of subclavian steal syndrome. Retrograde flow can also occur in the internal mammary artery.*

Subclavian Steal Syndrome (Thoracic Aorta DSA Evaluation)

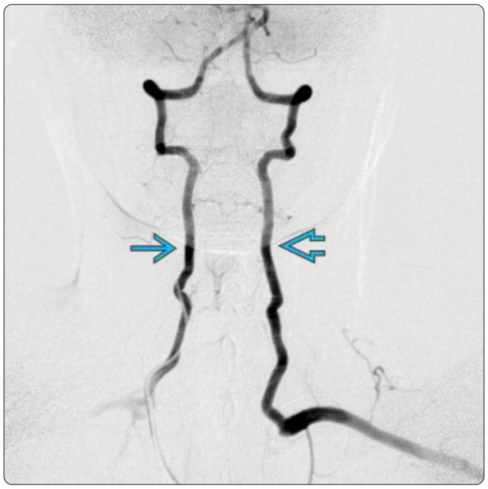


Subclavian Steal Syndrome (Thoracic Aorta DSA Evaluation)

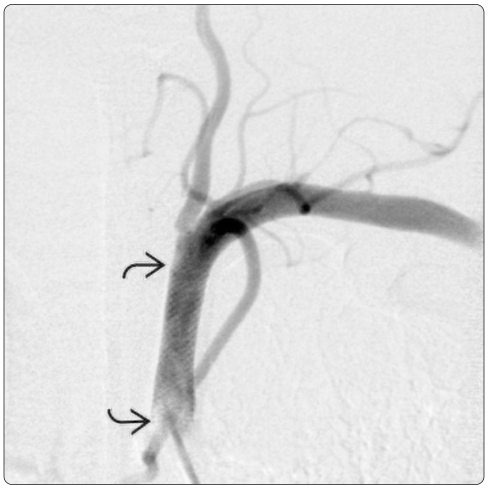


(Left) *Selective right vertebral DSA highlights the antegrade flow in the right → & retrograde flow in the left ⇨ vertebral arteries present in cases of subclavian steal syndrome.* **(Right)** *After catheterizing the subclavian artery stump, a guidewire & catheter were placed across the occlusion. Angioplasty was performed, followed by noncovered stent ↪ placement. Return to antegrade flow has been shown to occur over 20 seconds to 20 minutes.*

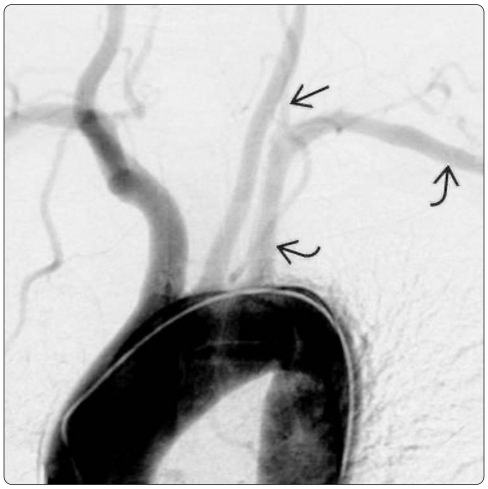
Subclavian Steal Syndrome (Right Vertebral Artery Injection)



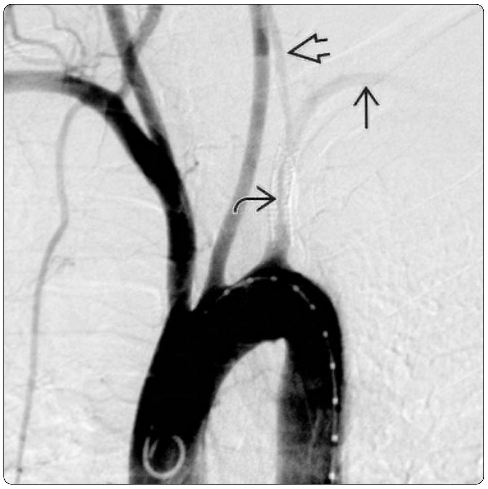
Subclavian Steal Syndrome (Recanalization & Stent Placement)



Subclavian Steal Syndrome (DSA Evaluation After Stenting)

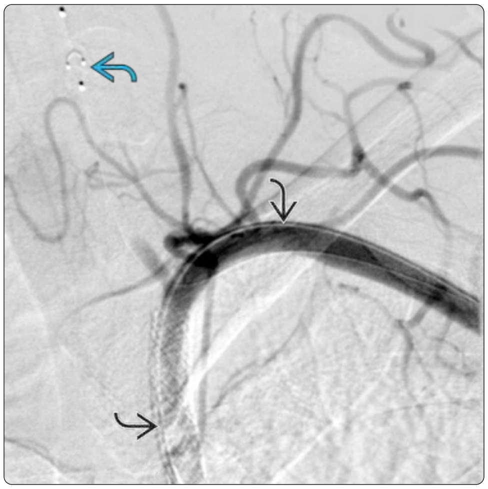


In-Stent Stenosis & Antegrade Vertebral Flow (Thoracic Aorta DSA)

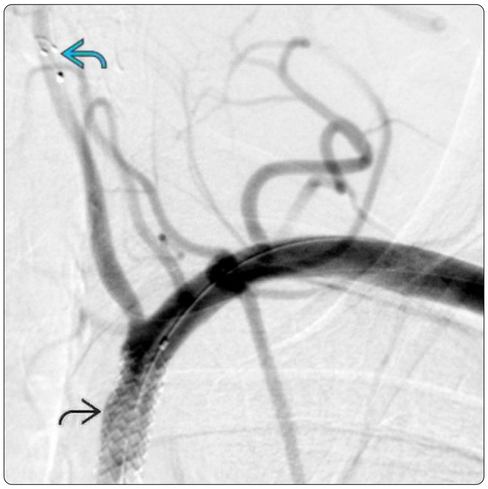


(Left) *DSA after stenting shows subclavian* → *&* *vertebral artery* → *patency. Long-term patency is less than with surgical bypass, but morbidity is lower.* **(Right)** *DSA of the thoracic aorta was performed & demonstrates a thin channel of contrast* → *coursing through the stent, indicating stenosis rather than occlusion. The left vertebral* → *& distal left subclavian* → *arteries are patent & opacify in a delayed but antegrade fashion.*

In-Stent Stenosis & Antegrade Vertebral Flow (Recanalization of Stent)

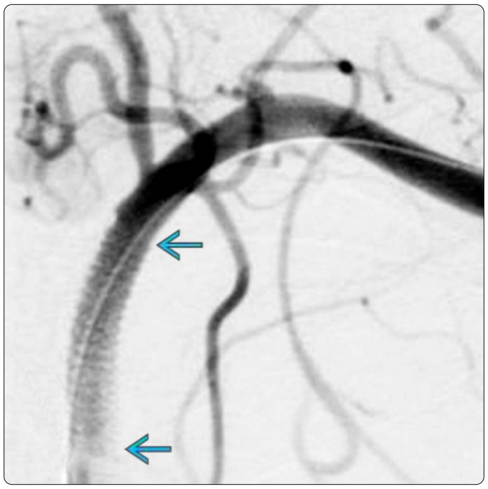


In-Stent Stenosis & Antegrade Vertebral Flow (Angioplasty + Embolic Protection)

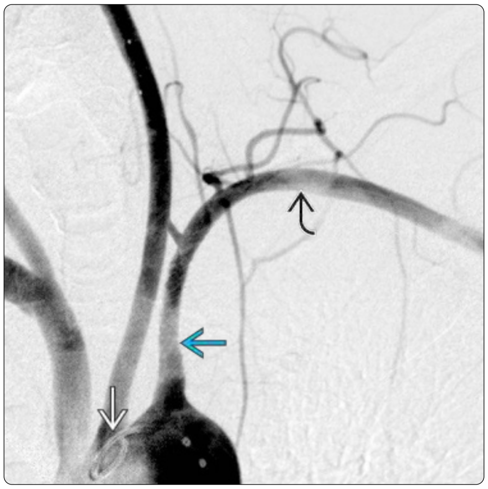


(Left) *Because of the antegrade flow in the left vertebral artery, an embolic protection device* → *was placed in the vessel from a retrograde brachial artery approach. A guidewire* → *was then advanced antegrade through the in-stent stenosis via a transfemoral arterial approach.* **(Right)** *Angioplasty of the in-stent stenosis was performed with the embolic protection device* → *in place. Although there was marked improvement in the luminal caliber* → *after angioplasty, there was residual narrowing seen proximally in the stent.*

In-Stent Stenosis & Antegrade Vertebral Flow (Additional Stent Placement)



In-Stent Stenosis & Antegrade Vertebral Flow (DSA Evaluation After Stenting)



(Left) *A 2nd noncovered stent* → *was placed overlapping the initial left subclavian artery stent. This new stent was extended more proximally to correct the residual stenosis that had been seen. DSA shows the stents are widely patent.* **(Right)** *After removing the embolic protection device, left subclavian artery catheter, & guidewire, DSA of the thoracic aorta was performed via a pigtail catheter* ➡*. This demonstrates a satisfactory result with a widely patent left subclavian stent* → *&* *native artery* →*.*

KEY FACTS

TERMINOLOGY

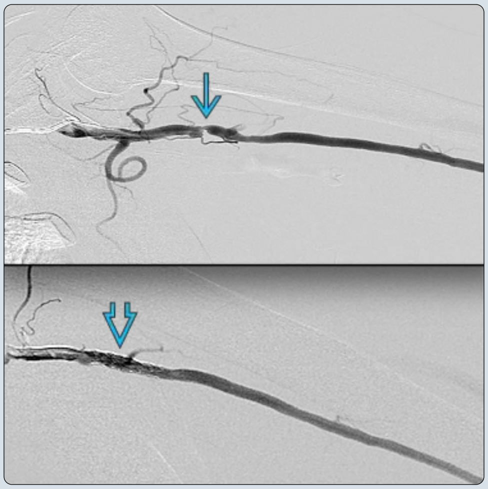
- **Hypothenar hammer syndrome**: Disorder caused by repetitive trauma to distal ulnar arterial segment coursing adjacent to hook of hamate
- **Radiation arteritis**: Permanent arterial damage caused by ionizing radiation; endothelial cells extremely vulnerable
- **Thoracic outlet syndrome**: Extrinsic compression of neurovascular structures exiting or entering thorax
- **Vasculitis & arteriopathies**
  - **Buerger disease (thromboangiitis obliterans)**: Inflammatory disease associated with tobacco, affecting small to medium-sized arteries & veins of extremities
  - **Fibromuscular dysplasia**: Noninflammatory segmental arteriopathy characterized by sequential thickening & thinning; arterial media most often involved
  - **Giant cell arteritis**: Vasculitis affecting medium to large-caliber arteries; similar to Takayasu arteritis & may represent single disease spectrum
  - **Raynaud phenomenon**: Disorder characterized by episodic digital artery vasospasm/vasoconstriction
  - **Takayasu arteritis**: Large-vessel granulomatous inflammatory vasculitis

PROCEDURE

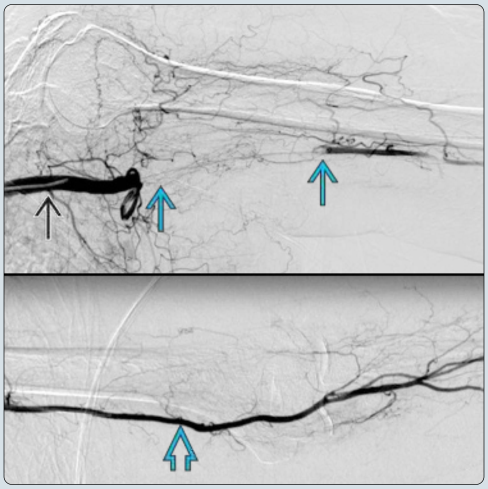
- Review cross-sectional imaging
- Obtain diagnostic arteriogram: Arch aortogram followed by upper extremity arteriogram
- Determine if endovascular intervention indicated
  - Determine appropriate access: Femoral, brachial, radial
  - Deliver systemic heparin
  - Introduce guiding sheath & catheter if femoral approach
  - Treat over stiff guidewire of sufficient length to facilitate planned angioplasty/stent equipment & to allow bailout equipment if complications occur
  - Avoid stent placement in any location susceptible to continuous or prolonged extrinsic compression (e.g., thoracic outlet)

(Left) *Hand numbness and decreased strength resolved in this patient following endovascular stenting* → *of high-grade brachial artery stenosis* →. **(Right)** *An 87-year-old woman with atrial fibrillation presented with an acutely painful and cold left hand. An arteriogram via an axillary catheter* → *revealed an 11-cm-long proximal brachial artery occlusion* →. *Small collateral arteries maintain flow in the distal brachial artery* →. *This patient underwent intraoperative embolectomy with a good result.*

Stenosis of Brachial Artery (Endovascular Stent Deployment)

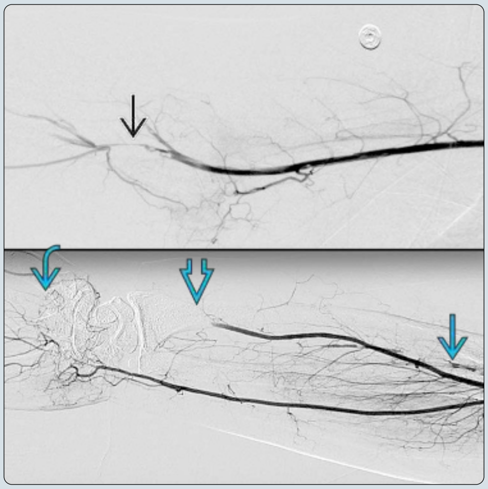


Thromboembolism of Proximal Brachial Artery (Surgical Embolectomy Required)

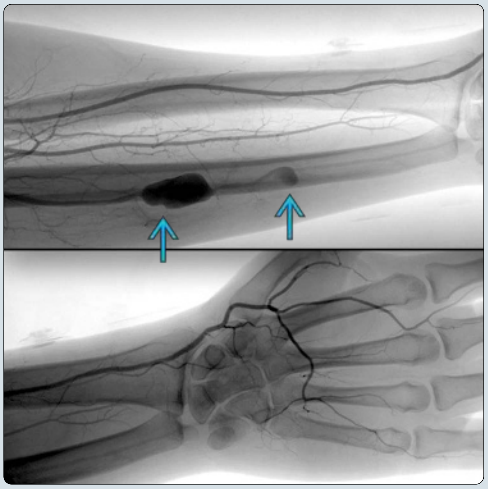


(Left) *A patent foramen ovale led to thromboemboli of the distal brachial artery* →, *interosseous artery* →, *distal radial artery* →, *and superficial palmar arch* →. *Treatment of distal forearm arteries is challenging due to their propensity to spasm. Flow improved after 48 hours of brachial artery infusion of tissue plasminogen activator (tPA).* **(Right)** *Ulnar artery aneurysms* → *can compress and irritate the ulnar nerve, as in this patient. Parethesia and weakness resolved completely following intraoperative aneurysm resection.*

Thromboembolism of Forearm and Hand (Endovascular Thrombolysis)



Ulnar Aneurysms (Surgical Resection Required)



TERMINOLOGY

Definitions

- **Buerger disease (thromboangiitis obliterans)**: Nonatherosclerotic inflammatory disease affecting small to medium-sized arteries & veins of extremities
  - Strongly associated with heavy tobacco use
  - Inflammatory cellular debris occludes vessel lumen
    - Extensive "corkscrew" collaterals around occlusions
      - Collaterals develop in vasa vasorum of occluded arteries; causes corkscrew appearance
  - Ischemic ulcers in toes & fingers later in disease course; reported in 40-50% of patients
  - Poor prognosis with progression of disease unless patients stop smoking
    - Common to progress to amputation
- **Frostbite**: Localized damage to skin & other tissues caused by extreme cold; often involves extremities
  - Pathophysiology of tissue injury in frostbite
    - Initial tissue freezing & crystal formation
      - Improves with tissue rewarming
    - Subsequent tissue inflammation & coagulation
      - Causes microvascular thrombosis/cell death
  - Injury spectrum ranges from irreversible cellular destruction to reversible changes after rewarming
    - Changes include tissue edema, circulatory stasis, progressive thrombosis causing tissue necrosis
    - Course similar to ischemia/reperfusion injury
      - Viable-appearing tissue may later necrose due to microcirculatory collapse after reperfusion
  - Conventional frostbite treatment
    - Patient resuscitation; intravenous hydration
    - Tissue rewarming in tepid water
    - Heparinization, intraarterial vasodilators
    - Monitoring of viable vs. nonviable tissue
      - Amputation as necessary
    - Generally poor overall clinical outcomes
  - Transcatheter thrombolysis treatment of frostbite
    - Intraarterial catheter-directed thrombolysis using tissue plasminogen activator (tPA) infusion
      - Reverses microvascular thrombosis before irreversible ischemia & necrosis occur
- **Hypothenar hammer syndrome**: Disorder caused by repetitive trauma to distal ulnar arterial segment coursing adjacent to hook of hamate
  - Ulnar artery has superficial course in Guyon canal
    - Repetitive pounding or vibrational activity can cause intimal or diffuse arterial injury
    - Injury may progress to aneurysm, arterial occlusion
      - May result in distal embolization with occlusion of palmar &/or digital arteries
      - Digital arterial occlusions occur in ulnar artery distribution (middle, ring, & small fingers)
    - May be diagnosed at stage in which irreversible consequences have already occurred
      - Often diagnosed too late for recanalization attempt to be viable therapeutic option
      - Digital gangrene requiring amputation possible
- **Raynaud phenomenon**: Disorder characterized by episodic digital artery vasospasm/vasoconstriction
  - 1° Raynaud phenomenon (Raynaud disease): Exaggerated smooth muscle cell vasoconstriction in otherwise normal digital artery; usually cold induced
    - No identifiable underlying arterial abnormality
    - Environmental trigger causes primary vasospasm
  - 2° Raynaud phenomenon (Raynaud syndrome): Vasospastic digital ischemia associated with underlying arterial pathology
    - Most commonly associated with cutaneous & connective tissue disorders
    - Triggered by cold, nicotine, caffeine, & stress
- **Thoracic outlet syndrome**: Clinical disorder caused by extrinsic compression of neurovascular structures exiting or entering thorax
  - May be predominantly neurogenic, venous, or arterial
    - Symptoms from arterial compression in < 5%
      - Pain, coolness, pallor, diminished pulses
      - Distal thromboembolic symptoms (e.g., ischemia, cyanosis) most common presentation
    - Clinical symptoms involve compression of brachial plexus & related nerves in > 90%
      - Pain, numbness, tingling, hand weakness
- **Vasculitis & other arteriopathies**
  - **Fibromuscular dysplasia (FMD)**: Nonatherosclerotic, noninflammatory segmental arteriopathy characterized by sequential thickening & thinning; arterial media most often involved
    - Although upper extremity FMD very rare, most commonly involves brachial artery when present
    - May have symptoms of upper extremity ischemia
      - Coolness, decreased pulses, pain, distal emboli
  - **Giant cell arteritis (GCA)**: Vasculitis affecting medium to large-caliber arteries; similar to Takayasu arteritis & may represent single disease spectrum
    - Age at onset often used to classify patients
      - GCA affects older population (> 50 years)
    - Traditionally considered to affect cranial arteries
      - Classically involves temporal arteries; may also involve cervical carotid arteries
    - 20-30% of patients with GCA have involvement of aorta & primary branches
      - May cause long stenoses of mid/distal subclavian arteries, extending into axillary arteries; seen more frequently in GCA than Takayasu
    - Diagnosis confirmed by arterial biopsy
      - Typically biopsy temporal artery; easily accessible, usually involved when disease present
      - Mononuclear cell infiltration/granulomatous inflammation with multinucleated giant cells
  - **Takayasu arteritis**: Large-vessel granulomatous inflammatory vasculitis
    - Affects people younger than 40 years
      - Often occurs between 15-30 years
    - Classically characterized by 3 stages
      - Active inflammation; constitutional symptoms
      - Vascular inflammation; vessel pain/tenderness
      - Vascular fibrosis or degeneration causing ischemia or aneurysms
    - Involves aorta &/or primary branches, pulmonary arteries

  - **Radiation arteritis**: Permanent arterial damage caused by ionizing radiation; endothelial cells extremely vulnerable; later involves media
    - Clinical/imaging manifestations generally follow 3 patterns; related to time interval since irradiation
      - Early lesions (within 5 years): Mural thrombus
      - Intermediate lesions (within 10 years): Mural fibrosis, occlusion, & absence of collaterals
      - Late lesions (mean interval: 26 years): Periarterial fibrosis & "accelerated atherosclerosis"
    - Presumptive diagnosis based on clinical history & angiographic appearance of lesions
      - History of irradiation in area of arterial lesion
      - Lesions often occur in atypical locations; adjacent arterial beds largely spared
      - Carotid, subclavian, axillary, & iliac arteries most commonly affected vascular territories
    - Revascularization procedures often difficult
      - Postradiation scarring/fibrosis may significantly impact open surgical revascularization
      - Lesions at thoracic outlet challenging for durable outcomes with endovascular intervention

Pertinent Vascular Anatomy

- **Axillary artery**: Originates at lateral margin of 1st rib; has 3 segments based on relationship to superficially located pectoralis minor muscle
  - 1st segment: Portion medial to pectoralis minor
    - Superior thoracic artery: Supplies 1st & 2nd intercostal spaces, upper serratus anterior
  - 2nd segment: Portion behind pectoralis minor
    - Thoracoacromial artery: Supplies pectoral & deltoid muscles; extends to clavicle/acromion
    - Lateral thoracic (external mammary) artery: Supplies serratus anterior & pectoralis major muscles, lateral structures of thorax/breast
  - 3rd segment: Portion lateral to pectoralis minor
    - Subscapular artery: Largest branch of axillary artery; supplies subscapularis muscle
    - Anterior circumflex humeral artery: Supplies humeral head, shoulder joint, upper biceps muscles
    - Posterior circumflex humeral artery: Supplies teres minor & deltoid muscles
- **Brachial artery**: Continuation of axillary artery beyond lower margin of teres minor muscle; divides into radial & ulnar arteries at antecubital fossa
  - **Radial artery**: Main artery of lateral forearm
    - Landmark for division between anterior & posterior compartments of forearm
    - Yields superficial palmar branch, which joins superficial palmar arch
    - Terminates in deep palmar arch, which joins with deep branch of ulnar artery
      - Deep palmar arch located more proximally
    - Supplies thumb (princeps pollicis artery), 2nd digit
  - **Ulnar artery**: Main artery of medial forearm
    - Typically larger than radial artery
    - Yields interosseous artery below radial tuberosity
      - Supplies deep anterior & posterior forearm
    - Distally divides into deep & superficial branches
    - Terminates in superficial palmar arch, which joins with superficial branch of radial artery
      - Superficial palmar arch located more distally
    - Supplies 4th & 5th digits; variable supply to 3rd

PREPROCEDURE

Indications

- Chronic ischemia from stenotic/occlusive disease
  - May present as upper extremity claudication, rest pain, ulceration, gangrene
- Acute ischemia due to thrombosis & embolus
  - May present with pale, cold, painful, pulseless upper extremity

Contraindications

- Upper extremity arteries of small caliber typically difficult to treat by endovascular intervention
  - Very prone to vasospasm
    - May lead to arterial thrombosis/occlusion
  - Interventions may place hand/digits at ischemic risk
- Relative contraindication to stent placement across lesions involving thoracic outlet
  - Higher likelihood of stent compression & fracture
  - May need surgical decompression, vascular bypass
- Uncorrectable coagulopathy
- Anaphylaxis to iodinated contrast medium

Preprocedure Imaging

- CTA
  - Excellent delineation of arterial anatomy & pathology
- MRA
  - Excellent delineation of arterial anatomy & pathology
    - Contrast & noncontrast techniques available
- US
  - Useful in diagnosis of suspected GCA
    - Color Doppler/duplex US of temporal arteries
      - Hypoechoic circumferential wall thickening (halo sign; 90% sensitivity, 70% specificity)
- PET
  - Detects vasculitis in earlier stages than angiography
    - Promising diagnostic tool in extracranial disease
    - Unsuitable for cranial/temporal artery evaluation
- DSA
  - Gold standard for detecting arterial pathology
  - Imaging guidance for transcatheter intervention

Getting Started

- Things to check
  - Clinical history & physical examination
    - Appropriate procedure indications
      - Always consider whether surgical revascularization more appropriate
    - Current medications
      - Any anticoagulants/antiplatelet agents
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal creatine; eGFR > 60
    - Complete blood count
      - Platelet count > 50,000/μL

    - Coagulation profile
        - ☐ International normalized ratio ≤ 1.5
        - ☐ Normal prothrombin time, partial thromboplastin time
  - Limit oral intake: NPO for 8 hours prior to procedure
    - If moderate sedation/general anesthesia planned
    - Take any oral medications with water sip
  - Obtain informed procedural/sedation consent
- Medications
  - Heparin
    - Various intraprocedural administration regimens
      - ☐ Bolus dose of 2,500-5,000 U; followed by infusion of 1,000 U/h
      - ☐ Loading dose of 50-100 U/kg; followed by continuous infusion of 15-25 U/kg/h
  - Vasodilator
    - Typical bolus dose of 100 μg nitroglycerin
    - Prevents/treats catheter-induced vasospasm

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Typically common femoral artery access
  - May consider ipsilateral upper extremity access

Procedure Steps

- **Diagnostic arteriogram**
  - Sterilely prepare/drape intended access site
  - Administer local anesthetic
  - Obtain arterial access; introduce access sheath
  - Obtain ascending aortogram
    - Advance flush catheter (e.g., pigtail, Omni Flush) proximal to brachiocephalic artery takeoff over guidewire
    - Ensure no bubbles in catheter/syringe; stroke risk
    - Optimize detector angle
      - ☐ Left anterior oblique (LAO): Projects left common carotid & subclavian origins
      - ☐ Right anterior oblique (RAO): Projects brachiocephalic bifurcation
    - DSA: Typically inject contrast 15-20 mL/sec, 20-30 mL total; 3-4 frames/sec
    - Subclavian arteries typically included in this DSA
  - Select subclavian/axillary arteries over guidewire (proximal to target)
    - Consider 5-Fr angled catheter (e.g., Davis, Vertebral, Berenstein)
    - Ensure wire & catheter do not enter left vertebral artery, which typically arises straight in line superiorly; advance catheter past vertebral artery origin
    - Unless contraindicated, consider intraprocedural heparinization, given small arterial calibers
    - Upper extremity arteriogram can usually be completed from this catheter location
  - Obtain upper extremity arteriogram
    - Prior to power injection, hand inject contrast ensuring reflux to vertebral artery does not occur
    - Brachial DSA: Typically inject contrast 3 mL/sec, 6-8 mL total; 3 frames/sec
    - Forearm DSA: Typically inject contrast 3 mL/sec, 6-12 mL total; 3 frames/sec
    - Hand DSA: Typically inject contrast 3 mL/sec, 10-15 mL total; 1-2 frames/sec, consider 3- to 5-second x-ray delay based on speed of flow
  - If catheter-induced vasospasm encountered
    - Administer intraarterial vasodilator (e.g., 100-200 μg nitroglycerin)
  - Determine most appropriate treatment: Conservative, angioplasty, stenting, thrombolysis
    - Take into account lesion location, caliber of artery, adjacent branch vessels, symptomatology, chronicity
    - Proceed to intervention if appropriate
- **Transcatheter interventions**
  - Consider introducing guiding sheath/catheter (typically 6-7 Fr, 70-90 cm from groin access) into upper extremity artery proximal to lesion
    - Provides stability during interventions
    - Facilitates coaxial introduction of devices/stents
    - Allows contrast injection between & after interventions
  - Consider new brachial/radial access, dependent on location of lesion
    - Brachial artery susceptible to access-related iatrogenic arterial injury, thrombosis, vasospasm
  - Repeat DSA, last-image hold or Roadmap via guiding sheath
    - Evaluate vascular anatomy: Runoff distal to lesion, critical branches potentially at risk, diameter of adjacent uninvolved artery
    - Evaluate lesion characteristics, including length
  - **Angioplasty & stent placement**
    - Strongly consider administering IV heparin prior to intervention
    - Cross lesion with soft/hydrophilic guidewire & coaxial catheter
    - Confirm intraluminal catheter position distal to lesion by small hand injection of contrast
    - Exchange for stiff guidewire of sufficient length to facilitate planned angioplasty/stent equipment
      - ☐ Wire should also be long enough to permit bailout equipment in case of complication during intervention
    - Position chosen balloon or stent across lesion
      - ☐ Rarely, will need to place guiding sheath beyond lesion to permit safe introduction of stent
      - ☐ PTA predilation of lesion may be needed to allow for stent introduction & placement
    - Angioplasty or deploy stent while fluoroscopically monitoring
    - Obtain final DSA via guiding sheath/catheter
      - ☐ Confirm satisfactory result
      - ☐ Exclude complications
- **Transcatheter thrombolysis**
  - Carefully consider appropriateness of thrombolysis
    - Catheter-induced thrombosis can occur in small-caliber arteries (e.g., forearm)
    - Distal embolization of thrombotic debris occurring during arterial thrombolysis can result in ischemic thromboembolic complications of hand

    - Stroke potential exists with prolonged sheath or catheter position crossing great vessels
  - Position infusion system across lesion ensuring that infusion sideholes extend proximal & distal to lesion
    - Initiate thrombolysis; typically tPA 1 mg/h, plus 400-600 U heparin/h via guide sheath
  - Repeat angiography after 12-24 hours of thrombolysis or sooner if there is clinical/laboratory indication to do so
  - May unmask underlying arterial lesions requiring secondary intervention (e.g., stent)
- **Transcatheter tPA thrombolysis treatment of frostbite**
  - Resuscitate patient; rewarm exposed tissues
  - Confirm < 24 hours of cold exposure time; warm ischemia time < 12-24 hours
  - Selectively catheterize brachial artery to treat hand
  - Continuous intraarterial transcatheter tPA infusion 1-2 mg tPA/h x 24 hours
  - Systemically heparinize patient

Alternative Procedures/Therapies

- Surgical
  - Bypass surgery
  - Endarterectomy
  - Open thromboembolectomy
- Other
  - **Raynaud phenomenon treatment**: Involves medical management; depends whether 1° or 2°
    - 1° Raynaud phenomenon
      - Avoid environmental triggers; use warm clothing
      - Conservative management; reassurance that digital ischemia/tissue loss rarely occurs
    - 2° Raynaud phenomenon
      - Requires medication more often than 1° form
      - Calcium-channel blockers used to relax smooth muscle & dilate small blood vessels
      - α blockers to counteract vasoconstrictive actions of norepinephrine
      - Medical treatment of underlying disorder
  - **Buerger disease management**
    - Total smoking cessation cornerstone of therapy
    - Meticulous hand & foot care
      - Hyperbaric oxygen therapy for ulcerations
    - If significant vasospasm present
      - Dihydropyridine calcium-channel blocker trial
    - Revascularization or PTA usually poor options
      - Diffuse segmental & extreme distal distribution
      - May require amputation of digits
    - Limited data on intraarterial thrombolytic therapy
  - **Vasculitis management**
    - High-dose glucocorticosteroids main therapy
    - Methotrexate, azathioprine therapy also used
    - ~ 25% of upper/lower extremity vasculitis cases require revascularization
      - Surgical bypass, endarterectomy, PTA, stent
  - **Radiation arteritis management**
    - Tailor to life expectancy, symptoms, & anatomy
    - Indications for intervention should not differ from those for atherosclerotic occlusive disease
      - Endovascular interventions often favored over surgical revascularization when possible

POST PROCEDURE

Things to Do

- Routinely use intraprocedural anticoagulation
  - Smaller-caliber arteries are prone to thrombosis
- Initiate antiplatelet agent therapy following endovascular interventions, such as PTA/stenting
  - Clopidogrel 300-mg loading dose; 75-mg daily dose
    - Minimum of 4-6 weeks therapy
  - Aspirin 81-mg or 325-mg strength
    - Continue indefinitely

Things to Avoid

- Routine stent placement across thoracic outlet
- Stent placement in any location susceptible to continuous/prolonged extrinsic compression

OUTCOMES

Problems

- Currently available endovascular devices limit treatable arterial segment in upper extremity
  - Thoracic outlet to antecubital fossa
    - Smaller distal arteries have poor stent patency rates & potential for thromboembolic complications
- Catheter-directed thrombolysis in upper extremity arteries may be problematic
  - Smaller caliber arteries prone to vasospasm

Complications

- Most feared complication(s)
  - Arterial thrombosis, distal embolization compromising circulation to hand, necessitating amputation
- Immediate/periprocedural complication(s)
  - Access site complications (e.g., hematoma, pseudoaneurysm, arteriovenous fistula)
  - Allergic/anaphylactic reaction to contrast
  - Contrast-induced nephropathy
- Delayed complication(s)
  - In-stent stenosis, stent occlusion/thrombosis
    - Can result in ischemia, distal embolization
    - May respond to secondary intervention
      - Angioplasty for in-stent stenosis, sometimes requiring placement of new stent
      - Thrombolysis for stent thrombosis
  - Restenosis at angioplasty site
    - May respond to repeat angioplasty/stent placement
  - Disease progression in treated segment or other segments of upper extremity arterial tree

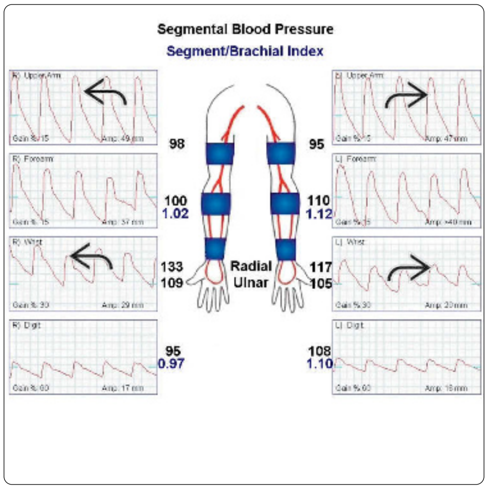
Expected Outcomes

- Restoration of patency to occluded arterial segment(s)
  - Satisfactory endovascular outcomes reported in multiple single-center studies
    - Typically involve larger-caliber arterial segments (e.g., axillosubclavian, proximal brachial)
  - No prospective, randomized, or long-term data

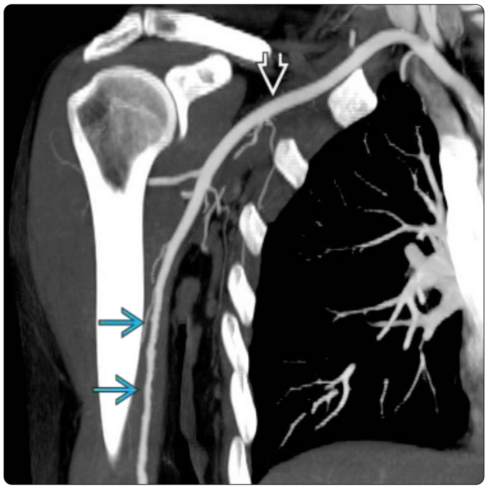
SELECTED REFERENCES

1. Wong VW et al: Interpretation of upper extremity arteriography: vascular anatomy and pathology [corrected]. Hand Clin. 31(1):121-34, 2015

Fibromuscular Dysplasia (Segmental Noninvasive Arterial Evaluation)

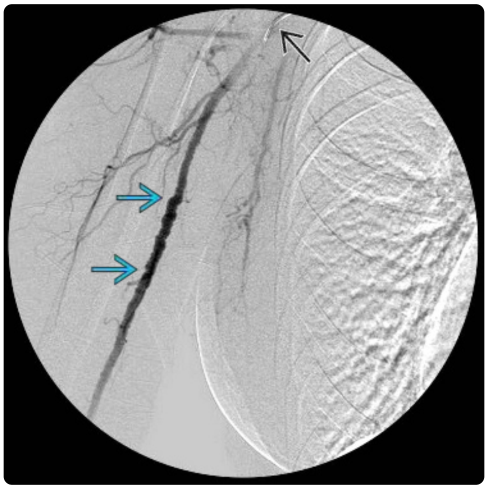


Fibromuscular Dysplasia (Coronal CTA)

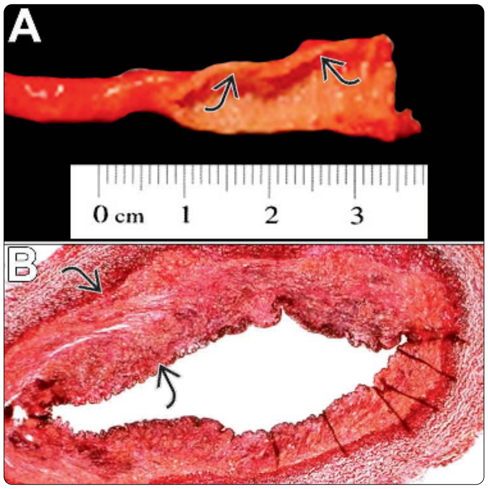


(Left) *A patient presented with scattered digital ulcerations. Arterial thoracic syndrome was suspected as the possible etiology, but the examination did not suggest a focal process. Instead, biphasic waveforms at multiple levels* ↷ *suggested a more diffuse process.* **(Right)** *Coronal CTA reconstruction shows a diffusely irregular contour to the brachial artery* ⇨ *as compared to the axillary artery* ➡. *This appearance is consistent with fibromuscular dysplasia (FMD) of the brachial artery.*

Fibromuscular Dysplasia (Right Brachial Artery DSA)

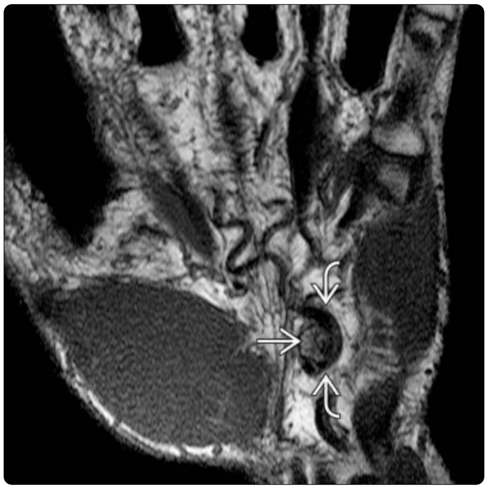


Fibromuscular Dysplasia (Pathology of Surgical Specimen)

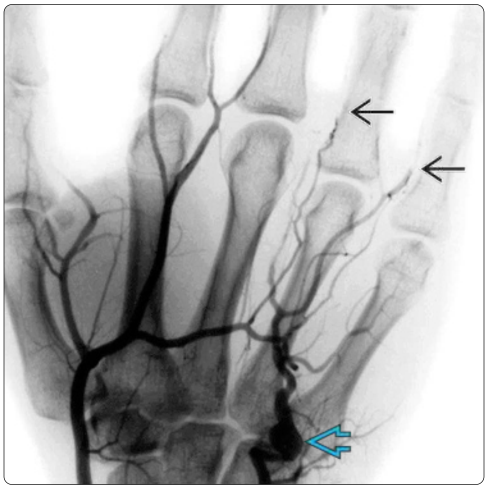


(Left) *DSA via a catheter* → *in the right axillary artery confirms diffuse FMD* ⇨ *of the brachial artery. This was successfully treated with angioplasty.* **(Right)** *The left brachial artery also exhibited FMD, but the artery was diminutive and was thus treated with arterial resection and reversed saphenous vein bypass. (A) Gross and (B) microscopic pathology of the resected artery shows the hyperplastic media* ↷ *that is typical of FMD.*

Hypothenar Hammer Syndrome (MR)

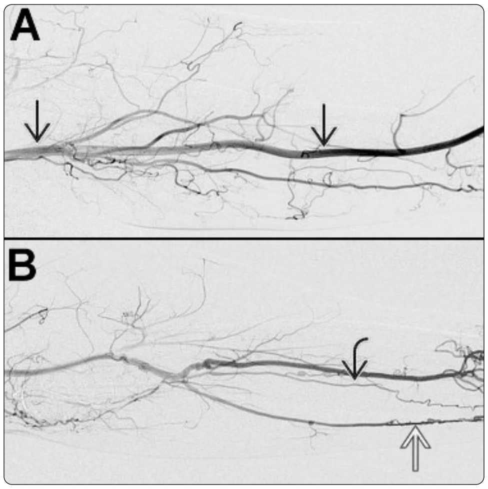


Hypothenar Hammer Syndrome (DSA)

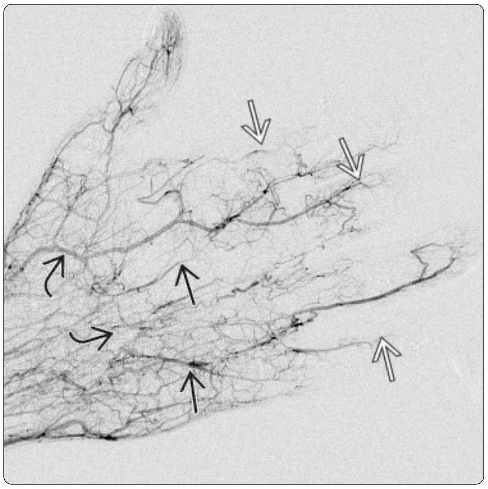


(Left) *MR in a patient with middle, ring, and small finger ischemia shows a distal ulnar artery aneurysm* ↷ *containing eccentric thrombus* ➡. *The location is typical of hypothenar hammer syndrome in which the segment of the ulnar artery coursing adjacent to the hook of the hamate sustains repetitive trauma.* **(Right)** *Unsubtracted right hand DSA shows an ulnar artery aneurysm* ⇨ *and multiple digital artery occlusions* → *secondary to distal emboli from thrombus within the aneurysm.*

Thromboangiitis Obliterans (Left Upper Extremity DSA)

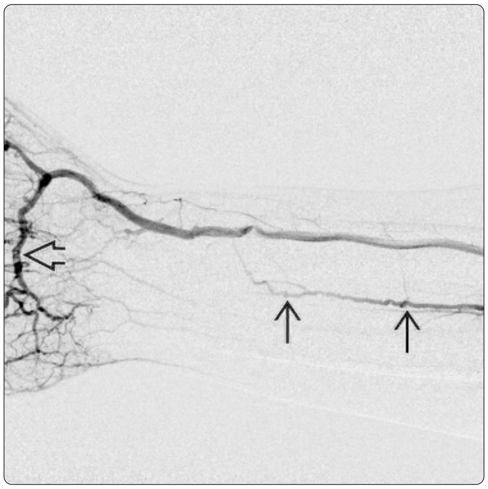


Thromboangiitis Obliterans (Left Hand DSA Evaluation)

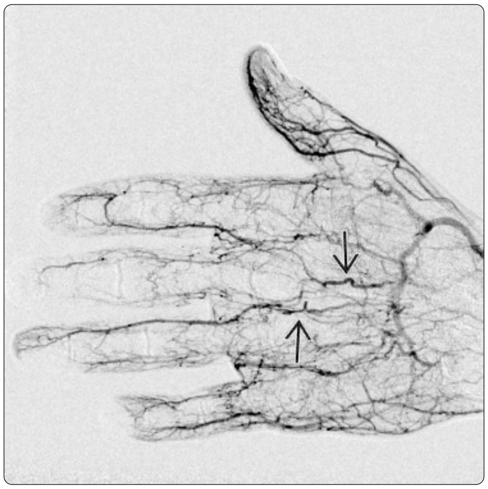


(Left) *A young male heavy smoker presented with severe ischemia of the fingers and toes. DSA of the left (A) upper arm and (B) forearm shows normal-caliber large arteries* → *with diseased medium-caliber arteries, such as the ulnar* ➡ *and median* ↪ *arteries.* **(Right)** *DSA shows more severe disease of the small-caliber arteries of the left hand. The superficial palmar arch* ↪ *and common digital arteries* → *are discontinuous, multiple proper digital arteries are occluded* ➡*, and the digital tufts are absent.*

Thromboangiitis Obliterans (Right Upper Extremity DSA)

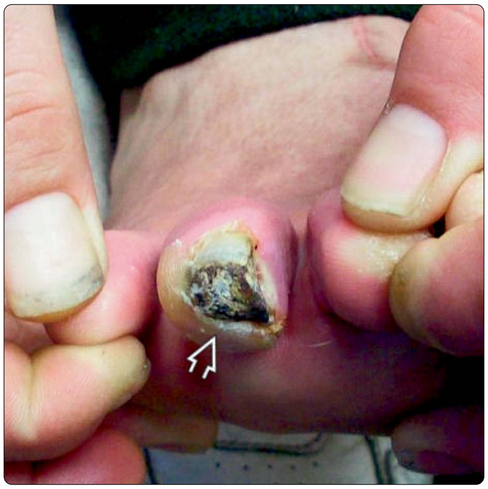


Thromboangiitis Obliterans (Right Hand DSA Evaluation)

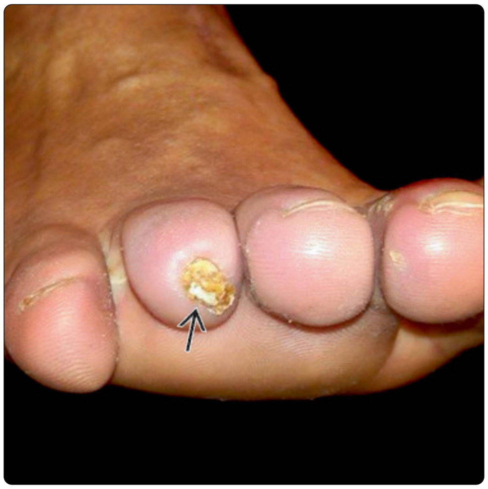


(Left) *DSA of the distal right forearm shows more severe disease with ulnar artery occlusion and a corkscrew appearance* → *to the median artery. The superficial palmar arch* ⇨ *is intact, however.* **(Right)** *Several vessels in the right hand have a corkscrew appearance* →*, and the proper digital arteries are severely diseased. The history, DSA appearance, and distribution are typical of Buerger disease (thromboangiitis obliterans). The corkscrew vessels represent enlarged vasa vasorum collaterals.*

Thromboangiitis Obliterans (Gangrenous Right 4th Toe)

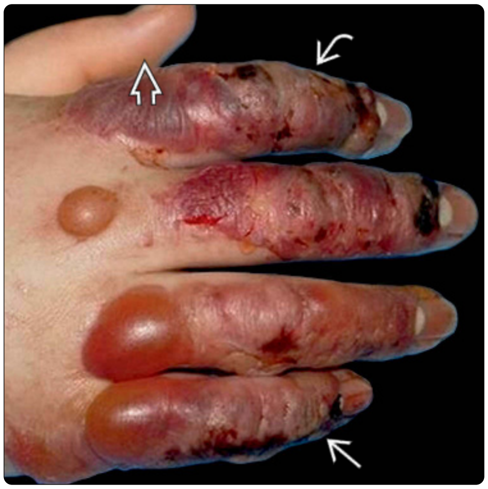


Thromboangiitis Obliterans (Hyperbaric Oxygen Therapy)

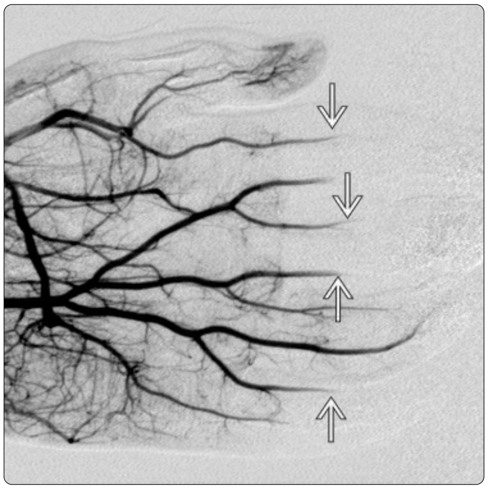


(Left) *Both feet were also involved, which is typical of this entity. Photograph of the right foot shows an ischemic 4th toe ulcer* ⇨ *with dry gangrene. Because the disease involves small-caliber arteries, endovascular or surgical revascularizations are rarely treatment options.* **(Right)** *Smoking cessation is imperative, as is meticulous hand and foot care. Hyperbaric oxygen therapy is often useful, as in this case. Photograph after several weeks of hyperbaric oxygen treatment shows near-total ulcer healing* →.

Frostbite (Appearance After Rewarming)

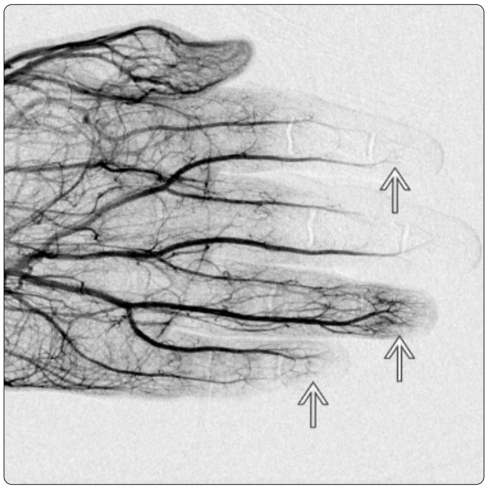


Frostbite (Initial Angiogram)

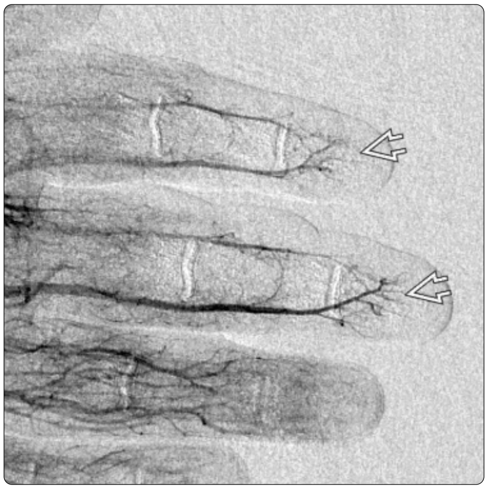


(Left) *Photograph shows the right hand of a patient with frostbite injury after rewarming in tepid water. The index* ➔ *through small* ➔ *fingers are most affected, and the thumb* ➔ *is unaffected. Typically during severe cold exposure, the thumb is clenched within the fist and is thus spared frostbite injury.* **(Right)** *Digital perfusion corresponds almost exactly to the clinical appearance of the hand. The proper digital arteries* ➔ *are not perfused beyond the proximal phalanges, with the exception of the thumb and ring fingers.*

Frostbite (Following Thrombolysis)

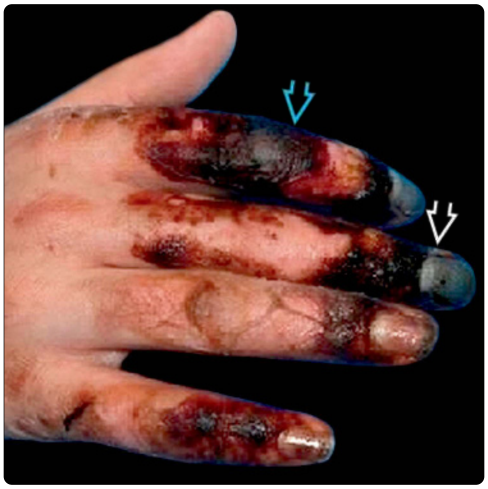


Frostbite (Following Thrombolysis)

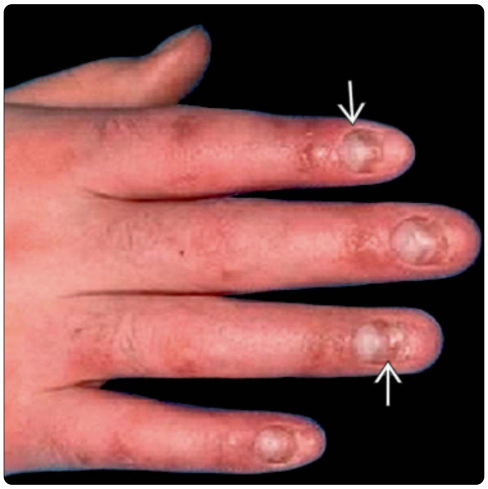


(Left) *Via transfemoral arterial access, infusion catheters were placed in both brachial arteries, and thrombolytic therapy was initiated. tPA was infused at a rate of 1 mg/h per catheter. DSA 24 hours after thrombolysis shows marked improvement in digital arterial perfusion* ➔ *compared to prethrombolysis images.* **(Right)** *Perfusion of the digital tufts* ➔ *is improved. Thrombolysis reverses microvascular thrombosis before irreversible ischemia and necrosis occur.*

Frostbite (1 Month After Injury)



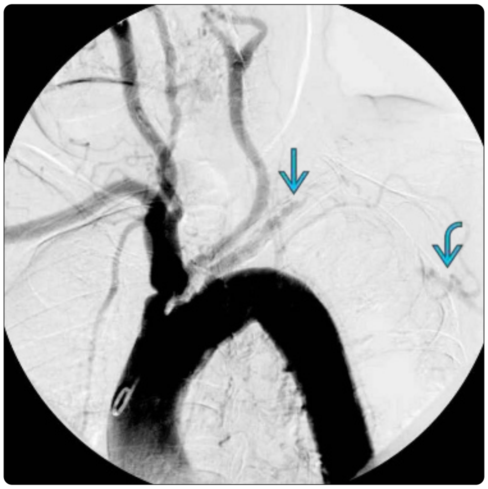
Frostbite (5 Months After Injury)



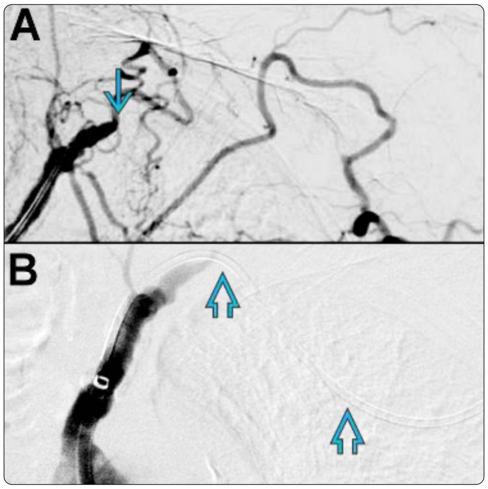
(Left) *Photograph of the right hand obtained 1 month after frostbite injury and transcatheter thrombolysis shows eschar in the same distribution as the original injury. The appearance also correlates very well with postthrombolysis DSA, as the index* ➔ *and distal middle* ➔ *fingers are most severely involved.* **(Right)** *Photograph of the right hand 5 months after injury and transcatheter treatment shows all digits are intact and exhibit new nail growth* ➔. *All of the left hand digits were also viable, and no amputations were required.*

(Left) *DSA in a woman with left arm claudication and a remote history (10 years prior) of left apical chest radiotherapy shows an irregular left subclavian artery that occludes proximally* → *and reconstitutes distally* ↪. **(Right)** *(A) Via transfemoral arterial access, the proximal left subclavian artery was catheterized and DSA obtained, confirming axillosubclavian artery occlusion* →*. (B) A catheter* ⇨ *advanced retrograde via left brachial artery access was able to negotiate through the occlusion.*

Radiation Arteritis (Axillosubclavian Occlusion)

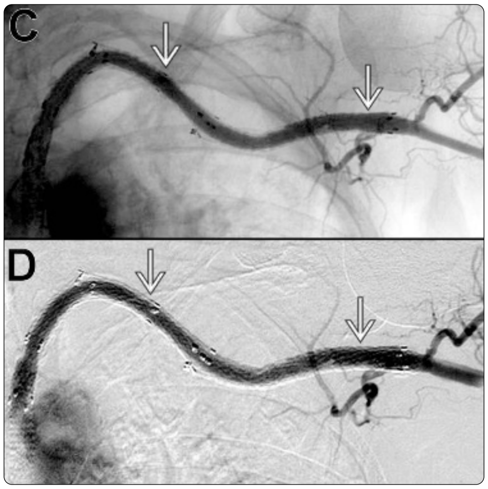


Radiation Arteritis (Transcatheter Recanalization)

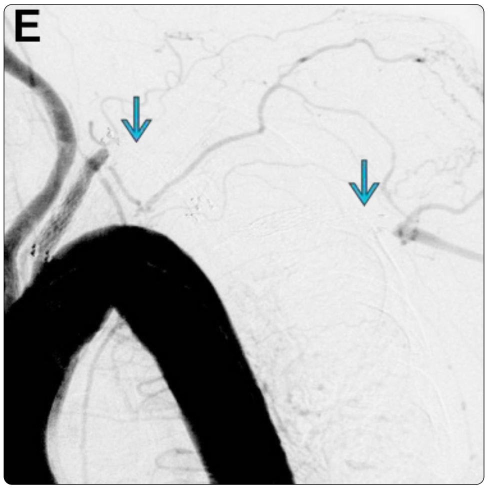


(Left) *After crossing the occlusion, a guidewire from the brachial access was snared into a transfemoral sheath placed in the subclavian artery. Covered stents* ➡ *were placed along the axillosubclavian arterial course via transfemoral access. (C) Unsubtracted and (D) subtracted DSA images show restoration of axillosubclavian arterial patency.* **(Right)** *Two months after stenting, the patient returned with recurrent symptoms and occlusion* → *of the stents.*

Radiation Arteritis (Revascularization via Stenting)

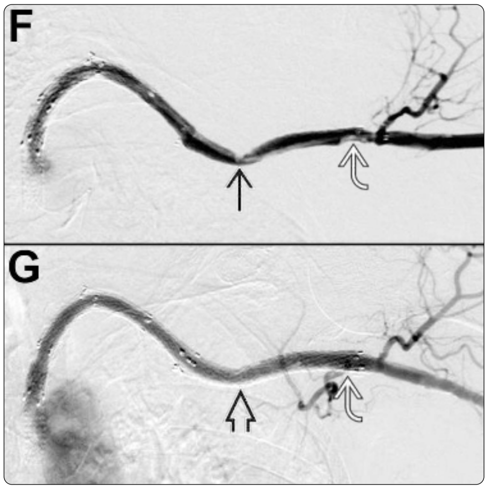


Radiation Arteritis (Thrombotic Occlusion of Stents)

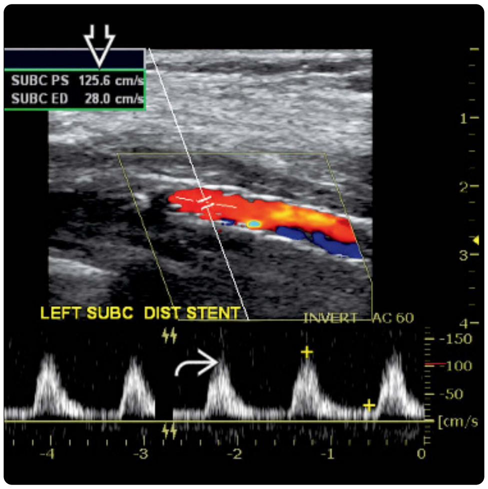


(Left) *(F) Via transbrachial artery access, thrombolysis via a multiple sidehole infusion catheter was performed. Postthrombolysis DSA reveals a kink* → *and distal stenosis* ↪*. (G) After angioplasty, a new stent was placed, eliminating both the kink* ⇨ *and distal stenosis.* **(Right)** *Subsequent Color Doppler ultrasound of the artery distal to the stents shows a normal peak systolic velocity* ⇨ *and an appropriate arterial waveform* ↪*. Close surveillance of stents crossing thoracic outlet is important, as they are prone to occlusion.*

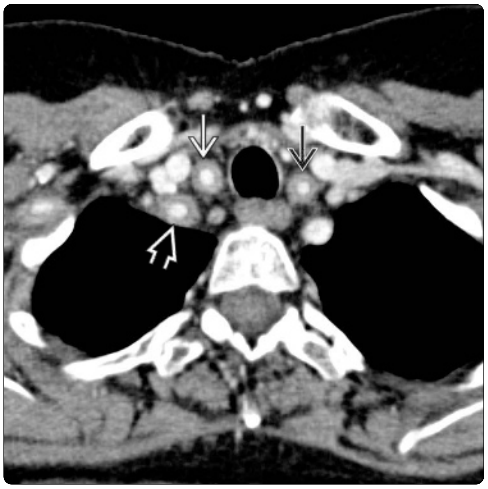
Radiation Arteritis (Successful 2° Reintervention)



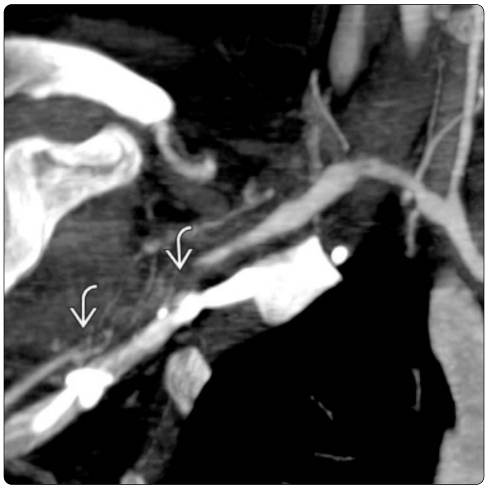
Radiation Arteritis (Color Doppler US Surveillance)



Vasculitis: Giant Cell Arteritis (Initial CECT Evaluation)

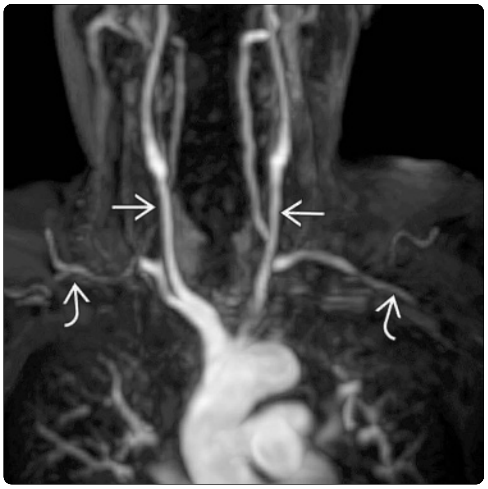


Vasculitis: Giant Cell Arteritis (Initial CECT Evaluation)

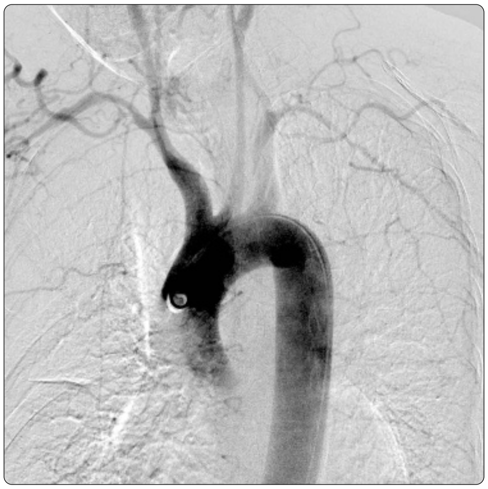


(Left) *A 55-year-old woman with myalgias, headaches, and upper extremity claudication has concentric wall thickening involving the right* ➡ *and left* ⇨ *common carotid and right subclavian* ➡ *artery. Arterial wall thickening, although nonspecific, is characteristic of a vasculitis.* **(Right)** *Segmental occlusion* ↪ *of the right axillary artery is also present. Giant cell and Takayasu arthritis may represent a single disease spectrum: Long stenoses of the subclavian and axillary arteries are seen more frequently in the former entity.*

Vasculitis: Giant Cell Arteritis (Gadolinium-Enhanced MRA)

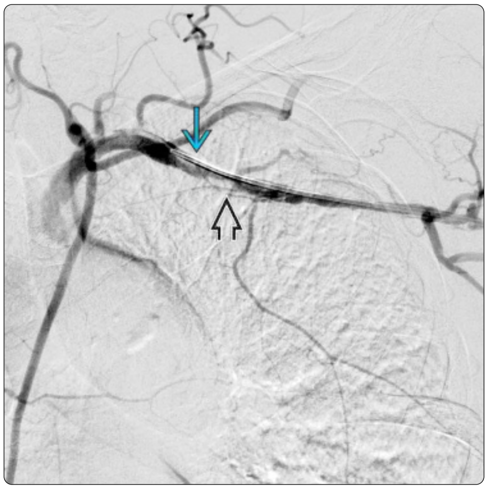


Vasculitis: Giant Cell Arteritis (Thoracic DSA Aortography)

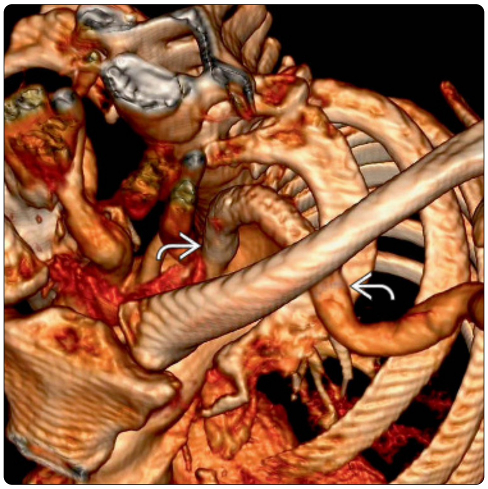


(Left) *Smooth narrowing of the cervical carotid arteries* ➡ *and more severe subclavian artery involvement* ↪ *are typical of giant cell arteritis.* **(Right)** *Bilateral subclavian artery PTA was planned. Roughly 25% of upper &/or lower extremity cases of giant cell arteritis require revascularization via various means, such as surgical bypass, thromboendarterectomy, and angioplasty. With high-dose corticosteroid therapy, 44% of patients will have complete clinical resolution and marked improvement of lesions.*

Complication: Iatrogenic Arterial Dissection (Coronal DSA)



Complication: Iatrogenic Arterial Dissection (Endovascular Stent Repair)



(Left) *DSA via brachial artery access shows a catheter* ⇨ *in the left subclavian artery and marked luminal irregularity* ⇨ *secondary to an iatrogenic arterial dissection. Clinically, the left upper extremity was ischemic with absent pulses.* **(Right)** *3D CTA reformation shows that an intravascular stent* ↪ *was placed in the left subclavian artery to revascularize the damaged arterial segment. This resulted in complete resolution of the ischemia and restoration of pulses.*

Upper Extremity Arteries: Exclusion

KEY FACTS

TERMINOLOGY

- **Axillary artery aneurysm**: Localized arterial dilatation ≥ 50% compared with normal diameter; may be true aneurysm or pseudoaneurysm
  - Pseudoaneurysms constitute majority of cases
  - True aneurysms relatively rare
- **Brachial artery aneurysm**: Same diameter criterion of ≥ 50% dilatation compared with normal diameter; may be true aneurysm or pseudoaneurysm
  - Pseudoaneurysms constitute majority of cases
  - Major morbidity if unrecognized/untreated
- **Thoracic outlet syndrome**: Clinical disorder caused by extrinsic compression of neurovascular structures exiting or entering thorax
  - Symptoms from arterial compression in < 5%

PROCEDURE

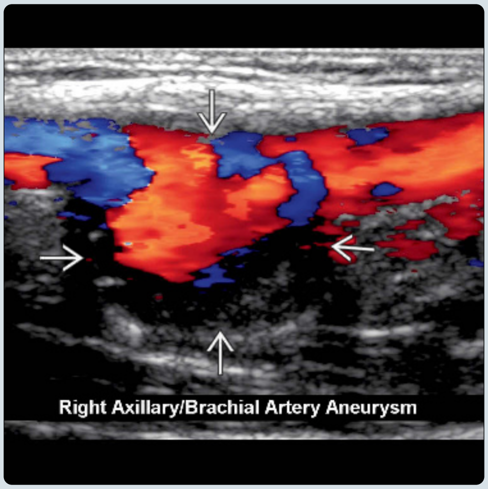
- Must determine whether surgical revascularization or endovascular intervention more appropriate
  - Endovascular intervention may be inappropriate in small-caliber arteries
- Place catheter in subclavian or axillary artery
  - Catheter tip proximal to target arterial segment
  - Inject contrast, obtain DSA images
- If intervention involves covered stent placement
  - Cross lesion with guidewire & coaxial catheter
  - Position chosen stent across lesion
  - Ensure no critical branches excluded by stent

OUTCOMES

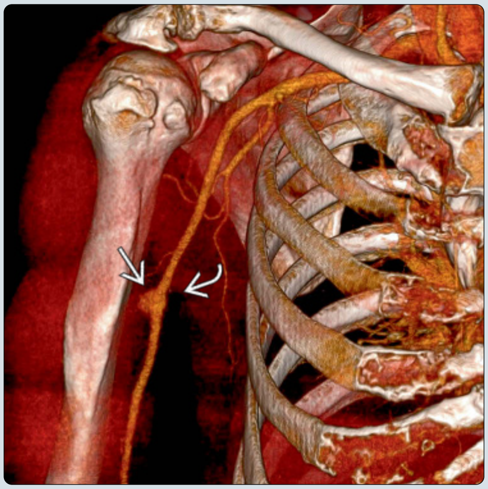
- **Most feared complication**
  - Distal embolization compromising hand circulation

(Left) *Sagittal color Doppler US of a patient who developed a pulsatile right axillary mass after prolonged use of crutches shows a focal aneurysm* ➔ *involving the transition from the axillary to the brachial artery.* **(Right)** *Coronal VR 3D CTA reformation confirms the focal aneurysm* ➔ *& shows its relationship to the axilla* ➔*. The repetitive blunt trauma associated with prolonged crutch use can result in true aneurysm formation in this location.*

True Aneurysm: Repetitive Blunt Trauma (Color Doppler US)

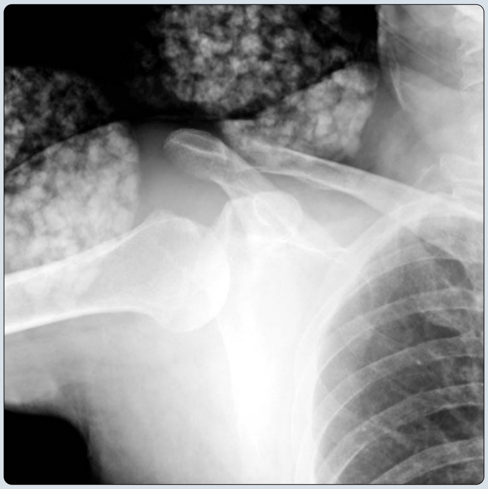


True Aneurysm: Repetitive Blunt Trauma (3D CTA)

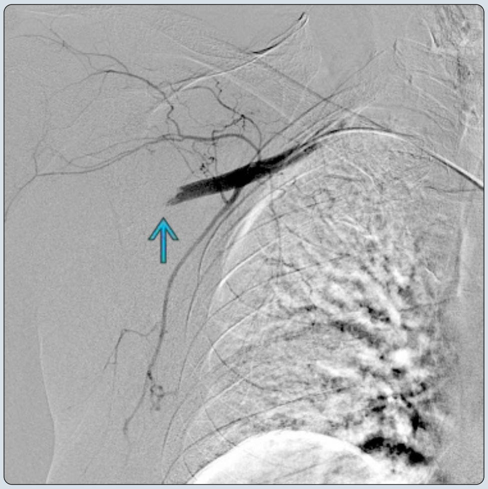


(Left) *True aneurysms may occur following repetitive blunt trauma. Pseudoaneurysms, active bleed, or ischemic distal thromboembolism can occur following blunt trauma, such as anterior shoulder dislocation seen here.* **(Right)** *Following relocation of the shoulder, DSA was performed, revealing an abrupt cutoff of the axillary artery* ➔*. Intraoperative exploration confirmed complete transection of the artery, which was subsequently repaired with a PTFE bypass graft.*

Thrombosed Arterial Transection (Anterior Shoulder Dislocation)



Thrombosed Arterial Transection (DSA After Shoulder Relocated)



TERMINOLOGY

Definitions

- **Axillary artery aneurysm**: Localized arterial dilatation ≥ 50% compared with normal diameter; may be true aneurysm or pseudoaneurysm
  - Pseudoaneurysms constitute majority of cases
    - Usually due to penetrating or iatrogenic trauma
    - May occur in association with blunt trauma
      - Humeral fracture, anterior shoulder dislocation
    - May also be due to postobstructive lesions in patients with thoracic outlet syndrome
    - Less frequently due to congenital arterial defects, infection, or vasculitis/vasculopathy
  - True aneurysms relatively rare
    - May occur with repetitive blunt trauma
      - Classically due to long-term crutch use
  - Major morbidity if unrecognized/untreated
    - Aneurysm/pseudoaneurysm rupture
    - Distal thromboembolism with ischemia
    - Brachial plexus compression; sensorimotor loss
- **Brachial artery aneurysm**: Same diameter criterion of ≥ 50% dilatation compared with normal diameter; may be true aneurysm or pseudoaneurysm
  - Pseudoaneurysms constitute majority of cases
    - Usually due to penetrating or iatrogenic trauma
      - Includes inadvertent arterial injection in IV drug abusers; can cause mycotic pseudoaneurysm
    - May occur in association with blunt trauma
      - Mid to distal humeral fracture
  - True aneurysms extremely rare
    - Most commonly related to repetitive blunt trauma
  - Major morbidity if unrecognized/untreated
    - Aneurysm rupture uncommon
    - Distal thromboembolism with ischemia may occur
      - 33% of asymptomatic lesions later become symptomatic
    - Pain/paraesthesia from median nerve compression
- **Thoracic outlet syndrome**: Clinical disorder caused by extrinsic compression of neurovascular structures exiting or entering thorax
  - May be predominantly neurogenic, venous or arterial
    - Symptoms from arterial compression in < 5%
      - Pain, coolness, pallor, diminished pulses
      - May have distal thromboembolic complications (e.g., cyanosis, digital ulceration, ischemia)
    - Clinical symptoms involve compression of brachial plexus/related nerves in > 90%
      - Pain, numbness, tingling, hand weakness
    - Various imaging manifestations of arterial thoracic outlet syndrome
      - Aneurysm ± mural thrombus
      - Arterial compression in costoclavicular space
      - Arterial thrombosis
      - Distal embolization/occlusion
      - Stenosis with poststenotic dilatation
- **Vascular laceration**: Complete/incomplete arterial transection
  - Most often due to penetrating or iatrogenic trauma
  - Clinical manifestations
    - Pulsatile bleeding or expanding hematoma
    - Absent distal pulses with cold, pale limb
    - Palpable thrill or audible bruit
  - Various imaging manifestations
    - Active contrast extravasation
      - May be due to partial arterial disruption or complete arterial transection
    - Formation of traumatic arteriovenous fistula
    - Pseudoaneurysm formation

Pertinent Vascular Anatomy

- **Axillary artery**: Originates at lateral margin of 1st rib; has 3 segments based on relationship to superficially located pectoralis minor muscle
  - 1st segment: Portion medial to pectoralis minor
    - Superior thoracic artery: Supplies 1st & 2nd intercostal spaces, upper serratus anterior
  - 2nd segment: Portion behind pectoralis minor
    - Thoracoacromial artery: Supplies pectoral and deltoid muscles; extends to clavicle/acromion
    - Lateral thoracic (external mammary) artery: Supplies serratus anterior & pectoralis major muscles, lateral structures of thorax/breast
  - 3rd segment: Portion lateral to pectoralis minor
    - Subscapular artery (largest branch of axillary artery): Supplies subscapularis muscle
    - Anterior circumflex humeral artery: Supplies humeral head, shoulder joint, upper biceps muscles
    - Posterior circumflex humeral artery: Supplies teres minor & deltoid muscles
- **Brachial artery**: Continuation of axillary artery beyond lower margin of teres minor muscle; divides into radial & ulnar arteries at antecubital fossa
  - **Radial artery**: Main artery of lateral forearm
    - Landmark for division between anterior and posterior compartments of forearm
    - Yields superficial palmar branch, which joins superficial palmar arch
    - Terminates in deep palmar arch, which joins with deep branch of ulnar artery
      - Deep palmar arch located more proximally
    - Supplies thumb (princeps pollicis artery), 2nd digit
  - **Ulnar artery**: Main artery of medial forearm
    - Typically larger than radial artery
    - Yields interosseous artery below radial tuberosity
      - Supplies deep anterior & posterior forearm
    - Distally divides into deep & superficial branches
    - Terminates in superficial palmar arch, which joins with superficial branch of radial artery
      - Superficial palmar arch located more distally
    - Supplies 4th & 5th digits; variable supply to 3rd

PREPROCEDURE

Indications

- Aneurysmal disease
  - Potential/actual thromboembolic complications
    - Aneurysms with laminar thrombus
      - Consider surgical vs. endovascular intervention
    - May require thrombolysis/revascularization
  - Mass effect on adjacent structures

- Nonaneurysmal lesions with potential/actual thromboembolic complications
  - Ulcerated atherosclerotic plaque
- Traumatic injuries (e.g., pseudoaneurysms, intimal disruption, active bleeding)
  - Must determine whether surgical revascularization or endovascular intervention more appropriate
    - Endovascular intervention may be inappropriate in small-caliber arteries (e.g., arteries distal to antecubital fossa)
    - Surgery may be higher risk in some situations (e.g., localized arterial injury amenable to covered/noncovered stent)

Contraindications

- Relative contraindication to stent placement across lesion crossing/involving thoracic outlet
  - Higher likelihood of stent compression/fracture
  - May need surgical decompression/vascular bypass
- Uncorrectable coagulopathy
- Anaphylaxis to iodinated contrast medium

Preprocedure Imaging

- CTA
  - Excellent delineation of arterial anatomy/pathology
- MRA
  - Excellent delineation of arterial anatomy/pathology
    - Contrast and noncontrast techniques available
- US
  - Color Doppler US useful for arterial screening
    - Aneurysm evaluation/characterization
    - Evaluation of flow hemodynamics
- DSA
  - Gold standard for detecting arterial pathology
  - Imaging guidance for transcatheter intervention

Getting Started

- Things to check
  - Clinical history and physical examination
    - Appropriate procedure indications
      - Always consider whether or not open surgical revascularization is more appropriate
    - Current medications
      - Any anticoagulants/antiplatelet agents
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - Complete blood count (CBC)
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ratio (INR) ≤ 1.5
      - Normal prothrombin time (PT), partial thromboplastin time (PTT)
  - Limit oral intake: NPO for 8° prior to procedure
    - If moderate sedation/general anesthesia planned
    - Take any oral medications with water sip
  - Obtain informed procedural/sedation consent
- Medications
  - Agents for moderate sedation (e.g., fentanyl, midazolam)
  - Heparin
    - Various intraprocedural administration regimens
      - Bolus 2,500-5,000 U, then 1,000 U/h infusion
      - Loading dose of 50-100 U/kg; followed by continuous infusion of 15-25 U/kg/h
  - Vasodilator (e.g., nitroglycerin)
    - Typical bolus dose of 100 μg nitroglycerin
    - Prevents/treats catheter-induced vasospasm

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Typically common femoral artery access
  - May consider ipsilateral upper extremity access
    - Antegrade axillary/high brachial artery access
    - Retrograde brachial artery access
      - Antegrade vs. retrograde access dependent upon lesion location/type of intervention
  - May occasionally require combined arterial access
    - e.g., both femoral & brachial artery access
- Positioning of upper extremity
  - Place arm board under affected upper extremity
    - Provides intraprocedural support for arm
    - Facilitates positioning during DSA imaging

Procedure Steps

- **Diagnostic arteriography**
  - Sterilely prepare/drape intended access site
  - Administer local anesthetic
  - Obtain arterial access; introduce access sheath
  - Choose appropriate diagnostic catheter
    - Use flush catheter for thoracic aortogram
      - e.g., pigtail, Omni Flush catheter
    - Use selective catheter for subclavian/axillary artery
      - e.g., Davis catheter
  - Introduce diagnostic catheter over guidewire
  - Position catheter appropriately for DSA
    - Aortic flush catheter proximal to target artery
      - e.g., proximal to brachiocephalic or left subclavian artery
    - Selective catheter in subclavian or axillary artery
      - Place catheter proximal to target arterial segment
      - Unless contraindicated, consider intraprocedural heparinization, given small arterial calibers
  - Inject contrast, obtain DSA images
    - Ensure appropriate overlap of imaging fields if evaluating multiple arterial segments
      - Must avoid omitting any portion of target(s)
    - Advance catheter tip more distally if needed
  - If catheter-induced vasospasm encountered
    - Administer intraarterial vasodilator
      - e.g., 100 μg nitroglycerin
    - Obtain repeat DSA images
  - Analyze DSA images
    - Identify/confirm abnormality
      - Evaluate lesion characteristics
    - Determine if transcatheter therapy appropriate
    - Determine if additional/alternate access needed
  - Proceed to intervention if appropriate

    - Document results with DSA after intervention
  - Remove catheters/sheaths; obtain hemostasis
- **Transcatheter intervention**
  - Consider introducing guiding sheath/catheter
    - Position sheath proximally (near lesion)
      - Facilitates coaxial introduction of devices/stents
      - Allows contrast injection during intervention
  - **Covered stent placement**
    - Cross lesion with guidewire & coaxial catheter
      - Hydrophilic guidewire/catheter typically useful
      - Consider roadmap guidance
    - Inject contrast via guiding sheath/catheter
      - Obtain DSA images
    - Analyze DSA images
      - Reevaluate vascular anatomy, lesion characteristics
      - Assess for any critical branches to be preserved
      - Evaluate arterial runoff distal to lesion
      - Determine appropriate stent diameter/length
      - Confirm guidewire/catheter distal to lesion
    - Exchange for stiff guidewire if necessary
      - Facilitates device introduction
      - Be certain to choose guidewire of adequate length for introduction/exchanges of catheters/devices
    - Position chosen stent across lesion
      - May first need to place guiding sheath beyond lesion to permit safe introduction of stent
    - Deploy stent while fluoroscopically monitoring
    - Obtain final DSA via guiding sheath/catheter
      - Confirm satisfactory result
      - Exclude complications
  - **Transcatheter embolization**
    - Consider using coaxial microcatheter
      - Facilitates selective catheterization of smaller caliber arteries/branches
      - Permits superselective embolization
  - **Combined transcatheter interventions**
    - May need concurrent catheter-directed thrombolysis or surgical thrombectomy if distal emboli present

Alternative Procedures/Therapies

- Surgical
  - Primary arterial repair or arterial bypass graft
    - Remains mainstay of aneurysm treatment
    - May also require open thromboembolectomy
  - Surgical decompression in thoracic outlet syndrome
    - Scalenectomy, 1st rib resection
- Other
  - Treatment of forearm arterial laceration
    - Direct manual pressure
    - Temporary pneumatic tourniquet inflation

POST PROCEDURE

Things to Do

- Clinical follow-up assessing upper extremity circulation
  - Imaging follow-up if symptomatic
    - CT/MR/US to evaluate stent patency

Things to Avoid

- Routine stent placement across thoracic outlet
- Stent placement in any location susceptible to continuous/prolonged extrinsic compression

OUTCOMES

Problems

- With currently available endovascular devices, treatable arterial segment in upper extremity is limited
  - Thoracic outlet to antecubital fossa
    - Poor patency rate in smaller distal arteries
      - Potential for thromboembolic complications
- Arterial laceration: No evidence-based management guidelines, or professional/societal consensus guidelines, recommend treatment for forearm arterial laceration

Complications

- Most feared complication(s)
  - Distal embolization
    - Compromised circulation to hand necessitating amputation
- Immediate/periprocedural complication(s)
  - Access site complications
    - Hematoma, pseudoaneurysm, iatrogenic arteriovenous fistula formation
  - Allergic/anaphylactic reaction to contrast
  - Contrast-induced nephropathy
- Delayed complication(s)
  - Stent occlusion/thrombosis with distal embolization
    - Stents susceptible to deformity/fracture, particularly if placed across thoracic outlet
    - Intimal hyperplasia/in-stent stenosis may occur

Expected Outcome

- Report of 9 patients who underwent endovascular treatment for aneurysm or traumatic injury showed
  - Technical success: 100%
  - 29-month mean follow-up
    - Primary patency: 89%
    - Secondary patency: 100%

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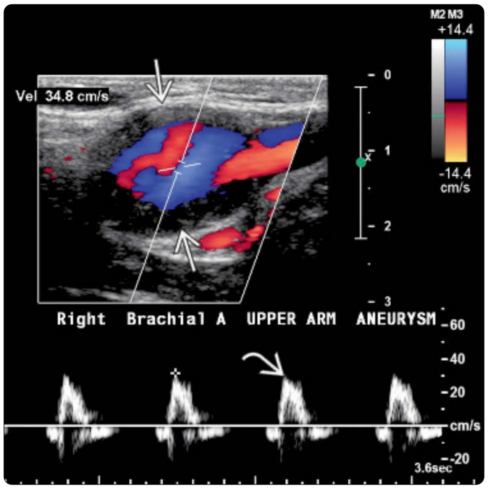
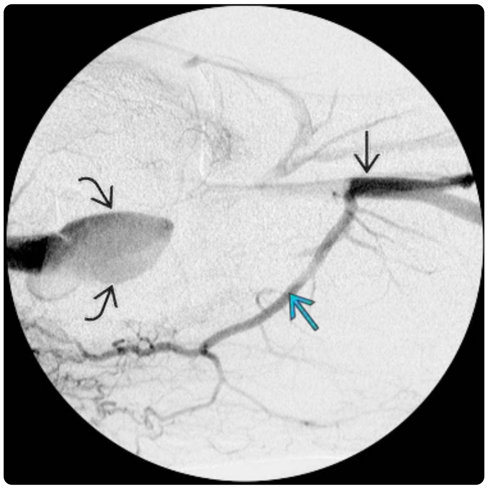
(Left) *Color Doppler US was obtained in a patient who developed a pulsatile mass in the right antecubital fossa following a penetrating injury. This sagittal image shows that the mass is vascular, as suspected, and has an arterial waveform ↪, c/w a brachial artery pseudoaneurysm ➡.* **(Right)** *Subsequent DSA angiography shows the proximal portion of the pseudoaneurysm ↪ but fails to demonstrate direct communication with the distal brachial artery segment ⇨. The latter fills via an arterial collateral ⇨.*

Brachial Artery Pseudoaneurysm (Initial Color Doppler US)

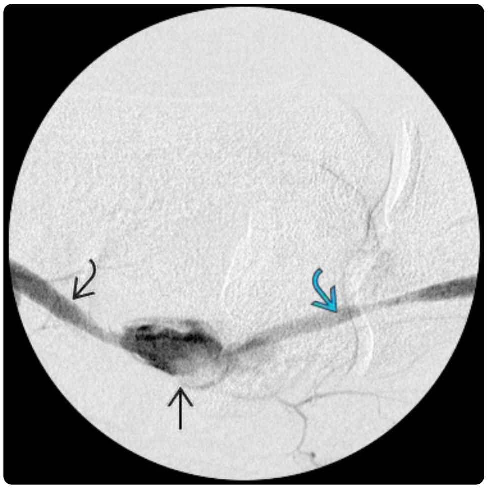


Brachial Artery Pseudoaneurysm (Diagnostic DSA Arteriogram)

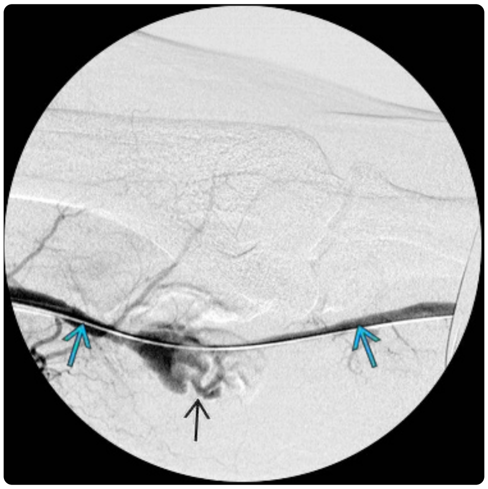


(Left) *The catheter that had been placed in the axillary artery for the initial DSA was repositioned in the brachial artery proximal to the pseudoaneurysm. Repeat DSA shows the pseudoaneurysm ⇨ & demonstrates its communication with the uninjured proximal ↪ & distal ↪ brachial artery segments.* **(Right)** *A guidewire ⇨ was carefully advanced through the pseudoaneurysm ⇨ into the distal brachial arterial segment and was positioned bridging the arterial injury in preparation for endovascular aneurysm exclusion.*

Brachial Artery Pseudoaneurysm (Diagnostic DSA Arteriogram)

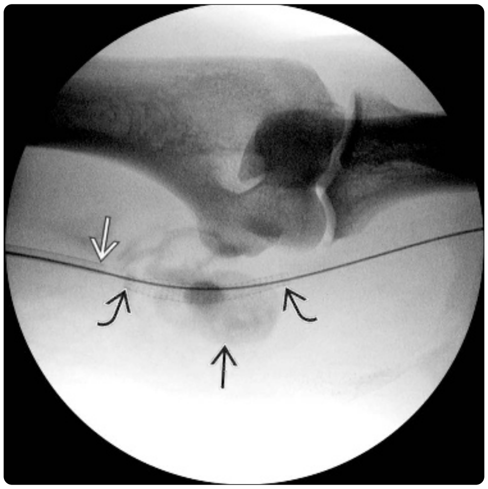


Brachial Artery Pseudoaneurysm (Guidewire Across Lesion)

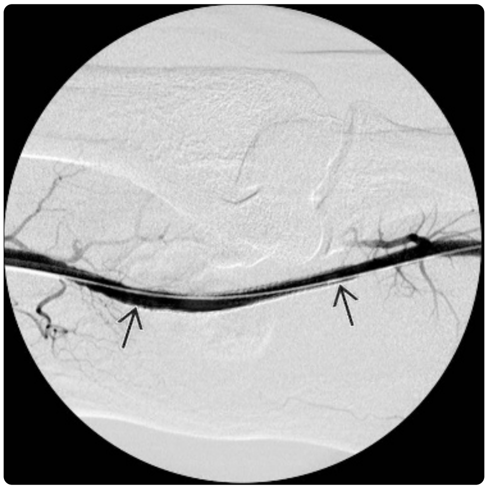


(Left) *A self-expanding, covered stent ↪ was introduced via a sheath ➡ & deployed across the pseudoaneurysm. Contrast in the pseudoaneurysm ⇨ localizes it relative to the stent.* **(Right)** *Additional covered stents were placed proximally & distally to completely exclude the pseudoaneurysm. It is important that the stents terminate in uninjured arterial segments in order to isolate the injury. Final DSA shows complete pseudoaneurysm exclusion via patent covered stents ⇨.*

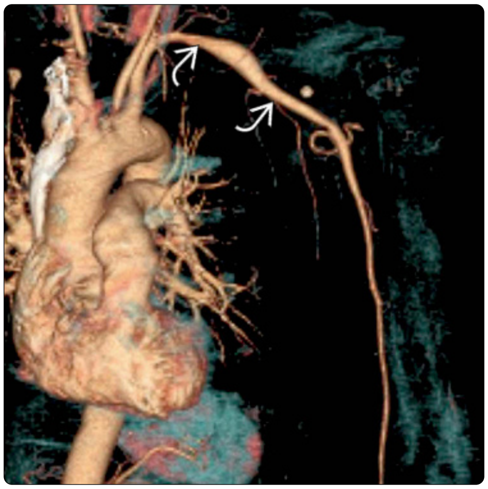
Brachial Artery Pseudoaneurysm (Initial Covered Stent Placement)



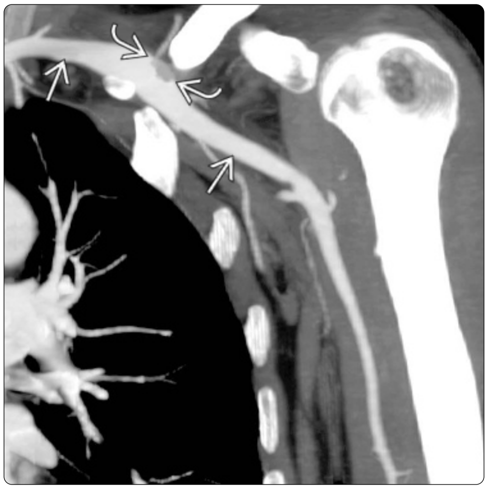
Brachial Artery Pseudoaneurysm (Final DSA After Additional Stents)



Axillosubclavian Artery Aneurysm (Thoracic Outlet Syndrome)

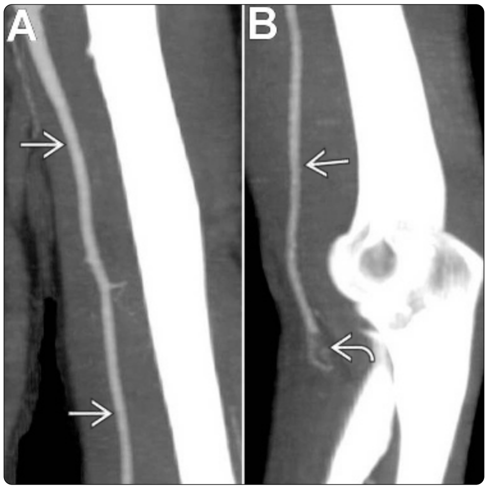


Axillosubclavian Artery Aneurysm (Laminar Intraluminal Thrombus)

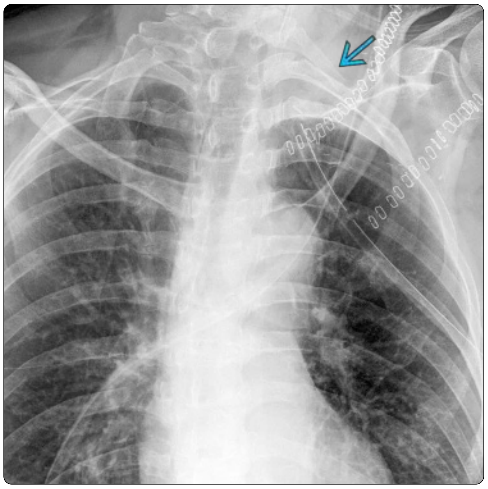


(Left) *An axillosubclavian artery aneurysm* ↪ *resulted from chronic extrinsic arterial compression at the thoracic outlet in the costoclavicular space. Arterial manifestations of thoracic outlet syndrome occur in < 5% of patients. When symptomatic, the most common clinical presentation is one of distal thromboembolism, such as cyanosis, digital ulceration, & ischemia.* **(Right)** *Coronal CTA again shows the fusiform aneurysm* ➔ *and also demonstrates the presence of mural thrombus* ↪ *within.*

Axillosubclavian Artery Aneurysm (Distal Thromboembolic Occlusion)

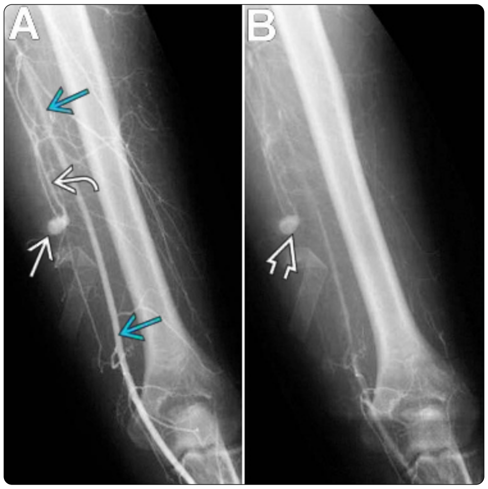


Axillosubclavian Artery Aneurysm (Postoperative Chest Radiograph)

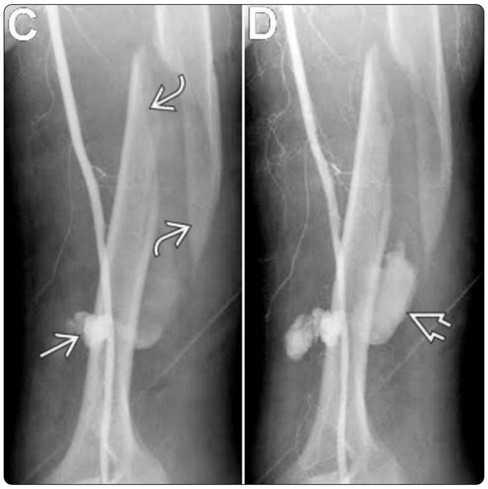


(Left) *CTA of (A) the upper arm and (B) elbow and upper forearm regions shows a patent brachial artery* ➔ *that occludes at the bifurcation into the radial and ulnar arteries. Intraluminal embolic filling defects* ↪ *typically lodge at bifurcations, as in this case.* **(Right)** *The patient underwent surgical embolectomy, 1st rib resection* ➔*, & aneurysmectomy with arterial bypass. Covered stent placement for aneurysm exclusion was considered, but this would still require surgical decompression & embolectomy or thrombolysis.*

Traumatic Brachial Arterial Injury (Pseudoaneurysm From Stab Wound)



Traumatic Brachial Arterial Injury (Arterial Laceration From Fracture)



(Left) *(A) A patient with a stab wound has a pseudoaneurysm* ➔ *fed by a branch* ↪ *arising from a normal brachial artery* ➔*. (B) The pseudoaneurysm* ⇨ *is unchanged in the late arterial phase, with no extravasation. The lesion would be amenable to coil embolization.* **(Right)** *In a different patient with a humerus fracture* ↪*, (C) extravascular contrast* ➔ *adjacent to the brachial artery (D) increases* ⇨ *on later imaging, c/w extravasation. Either surgical repair or endovascular exclusion is appropriate.*

KEY FACTS

TERMINOLOGY

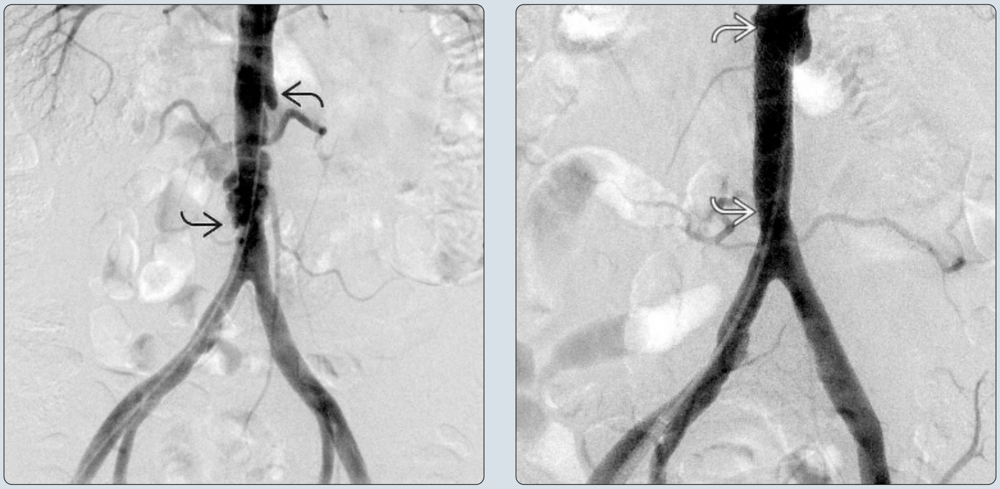
- **Acute aortic syndromes**: Spectrum of abnormalities that acutely compromise aortic wall integrity
  - Abdominal aortic dissection
  - Intramural hematoma
  - Penetrating atherosclerotic aortic ulcer
  - Symptomatic aortic aneurysm
- **Abdominal aortic stenotic/occlusive disease**
  - Atherosclerosis most common cause; ulcerated plaque may cause emboli to lower extremities
  - Coarctation disorders including neurofibromatosis, Takayasu arteritis, middle aortic syndrome

PROCEDURE

- **Acute aortic syndromes**
  - Some stable entities may be medically managed
  - When intervention indicated, typically managed by aortic endograft placement or surgery
- **Abdominal aortic stenotic/occlusive disease**
  - Stenosis location/relationship to branch vessels major determinant of optimal treatment
- **Ulcerated plaque with distal embolization**
  - Bare/covered stent placement to trap underlying pathogenic atherosclerotic lesion
- **Inflammatory stenosis (e.g., Takayasu aortitis)**
  - May require multiple prolonged balloon inflations
  - Typically avoid primary stent placement

OUTCOMES

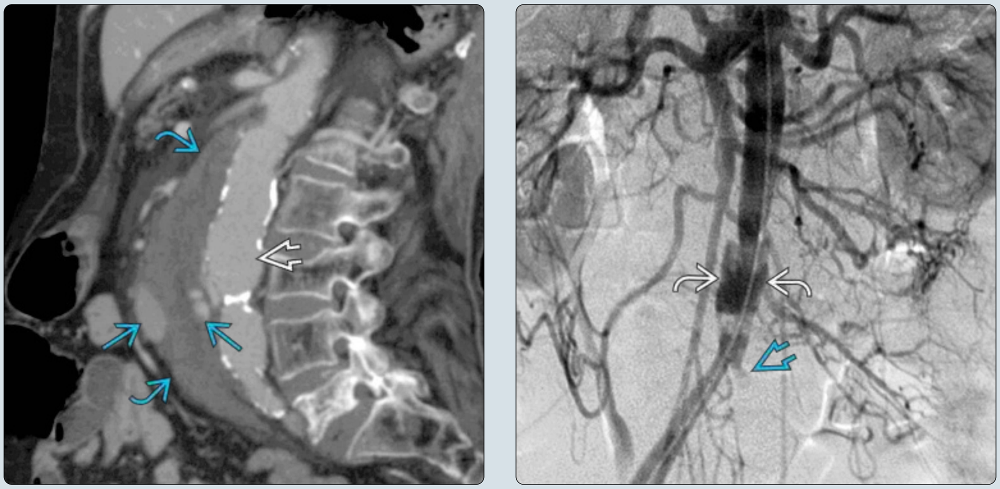
- **Acute aortic syndromes**
  - When intervention indicated, typically managed by aortic endograft placement or surgery
- **Atherosclerotic stenosis/ulcerated plaque**
  - High stenting success rates in appropriate lesions
- **Most feared complication(s)**
  - Vessel rupture
  - Macro-/microembolization during DSA/intervention
  - Branch vessel occlusion during PTA/stenting



Ulcerated Plaque in Abdominal Aorta Causing Blue Toe Syndrome: Evaluation

Ulcerated Plaque in Abdominal Aorta Causing Blue Toe Syndrome: Treatment

(Left) *DSA of the infrarenal abdominal aorta shows a lengthy and diffuse area of ulcerated plaque* ↪ *in the infrarenal aorta, extending inferiorly toward the aortic bifurcation, in a patient who presented with blue toe syndrome caused by distal microemboli to both feet.* **(Right)** *A stent was placed spanning the diseased segment. DSA shows the stent* ↪ *has excluded the ulcerated plaque, thereby eliminating the nidus for recurrent microemboli. However, the inferior mesenteric artery no longer fills after stenting.*



Seat Belt Injury of Abdominal Aorta: Initial CTA Evaluation

Seat Belt Injury of Abdominal Aorta: Initial DSA Evaluation

(Left) *CTA of the abdomen shows an extensive hematoma* ↪ *located anterior to the abdominal aorta* ➡*, with several foci of active contrast extravasation* → *within the hematoma. The patient had been involved in a high speed motor vehicle accident and was wearing a seat-belt. The location and appearance are typical of this injury.* **(Right)** *DSA shows an expanded aortic lumen* ↪ *at the level of the injury, reflecting a focal pseudoaneurysm. The left common iliac artery does not fill* ⇨ *due to the injury. The patient was treated via EVAR.*

TERMINOLOGY

Definitions

- **Abdominal aortic aneurysm (AAA)**: Localized aortic dilatation; exceeds normal diameter by > 50%
  - ~ 90% occur infrarenally
    - May be fusiform or saccular
    - May or may not involve iliac arteries
  - Considered multifactorial degenerative process
    - Proteolytic degradation of tunica media
      - ☐ Basic pathophysiology of AAA development
    - Significant association with atherosclerosis
    - Genetic influence; high familial prevalence
  - Inflammatory aneurysms occur in up to 10%
    - Aortic wall thickening; periadventitial fibrosis
      - ☐ May be symptomatic with fever/pain
      - ☐ May be immune-mediated process
      - ☐ Immunoglobulin G4-related disease reportedly among various causes of inflammatory AAA
  - Infectious (mycotic) AAA occur in 2%
    - Usually due to local bacterial seeding of diseased aortic wall or seeding via vasa vasorum
      - ☐ *Staphylococcus aureus*/*Salmonella* common
    - Known for rapid growth/rupture/high mortality
  - Heritable disorders (rare)
    - Whole-genome approaches being used to elucidate genetic basis of AAA and uncover genetic variants influencing disease risk
      - ☐ Marfan syndrome
      - ☐ Ehlers-Danlos syndrome type IV
- **Acute aortic syndromes**: Spectrum of abnormalities that acutely compromise aortic wall integrity
  - **Abdominal aortic dissection**: Intimal tear extends into aortic wall; blood flows between wall layers
    - Usually originates in thoracic aorta; may extend into or may originate in abdominal aorta
      - ☐ Tear typically extends antegrade; retrograde extension may also occur
    - Blood flow separates aortic wall structures, producing "true" and "false" lumens
      - ☐ Aortic branch vessel perfusion may be compromised; end-organ ischemia may result
    - Weakened aortic wall may rupture; high mortality
      - ☐ Chronic dissection may progress to aneurysm
  - **Intramural hematoma**
    - May occur as primary event in hypertensive patients
      - ☐ Spontaneous bleeding from vasa vasorum into aortic media causing hematoma formation
    - May result from penetrating atherosclerotic ulcer
    - Intramural hematoma weakens aortic wall
      - ☐ May progress to aortic dissection
      - ☐ Increased risk of aortic rupture
  - **Penetrating atherosclerotic aortic ulcer**: Plaque rupture through aortic internal elastic membrane
    - Subsequent intramural hematoma may occur
    - Ulcer/hematoma weakens aortic wall
      - ☐ May progress to aortic dissection
      - ☐ May form saccular pseudoaneurysm
      - ☐ Increased risk of acute rupture
  - **Symptomatic aortic aneurysm**
    - Acute onset of severe/continuous/worsening middle abdominal &/or back pain
      - ☐ Worrisome for impending AAA rupture
    - Ruptured AAA
- **Abdominal aortic stenotic/occlusive disease**
  - Atherosclerosis: Most common cause
    - Severe atherosclerotic stenosis may progress to chronic thrombotic occlusion
      - ☐ Acute aortic occlusion more often embolic
    - Leriche syndrome: Distal aorta/iliac occlusion
      - ☐ Absent femoral pulses, claudication, impotence
    - "Coral reef" plaque: Bulky, intraluminal, calcified plaque; may almost occlude aortic lumen
      - ☐ Frequently occurs in visceral aortic segment; may obstruct visceral/renal arteries
      - ☐ Distal embolization from bulky plaque common
    - Ulcerated aortic atherosclerotic plaque may be source of emboli to lower extremities
      - ☐ Emboli composed of cholesterol/thrombus/fibrin-platelet aggregates
    - Cholesterol embolization syndrome involves more diffuse cholesterol crystal embolization
      - ☐ Acute life-threatening event: Systemic emboli involving brain/eyes/kidneys/extremities
      - ☐ Complication of angiography, major vascular surgery, or thrombolytic therapy
      - ☐ Microembolization to lower extremities may cause "blue toe" syndrome
  - Coarctation disorders
    - Neurofibromatosis: Often involves vasculature
      - ☐ Aortic/branch stenoses (pararenal distribution)
      - ☐ Neurofibromatous proliferation in vessel wall
    - William syndrome: Rare congenital disorder
      - ☐ Aortic stenosis/developmental delay/elfin facies
    - Middle aortic syndrome: Unclear etiology
      - ☐ Narrowed mid-aorta/major visceral branches
      - ☐ Occurs in first 2 decades of life
  - Inflammatory etiology
    - Takayasu aortitis: Chronic progressive inflammatory disease affecting aorta/major branches/pulmonary arteries
      - ☐ Genetic/autoimmune components
      - ☐ Underlying chronic arterial inflammation
      - ☐ Extensive periarterial fibrosis/thickening
      - ☐ Noncompliant/rigid arterial walls
    - Other immune disorders affecting aorta
      - ☐ Behçet disease, polyarteritis nodosa (rare)
    - Infectious
      - ☐ Usually aneurysmal instead of occlusive disease
- **Traumatic aortic injury**
  - Penetrating: Involves abdominal > thoracic aorta
  - Blunt: Motor vehicle/crush injuries common
    - Seat belt deceleration injury can cause trauma to infrarenal abdominal aorta
    - Primary aortic lesions include rupture, intimal disruption/transection and pseudoaneurysm
  - High mortality rate

PREPROCEDURE

Indications

- **AAA**
  - Endovascular aneurysm repair (EVAR) size criteria
    - Diameter > 5.5 cm (men); > 5.0 cm (women)
    - AAA diameter > 2x normal aortic diameter
    - Rapidly expanding aneurysm (> 0.5 cm in 6 months)
  - Other criteria for intervention
    - Symptomatic or ruptured AAA
      - Categorized as one of acute aortic syndromes
    - Mycotic aneurysm or aortoenteric fistula
- **Acute aortic syndromes**
  - **Aortic dissection**
    - Compromised arterial perfusion due to compressed true aortic lumen; resultant ischemia
      - Restore arterial perfusion to ischemic vascular territories/end organs
      - Endovascular fenestration of dissection flap may be useful technique for restoring perfusion
      - Fenestration site should be as close as possible to compromised branch vessel origin
    - Dissection-related aortic aneurysm
  - **Intramural hematoma**
    - May be precursor to aortic dissection
      - Often managed medically by aggressive blood pressure reduction using β-blockers
      - Consider intervention if progresses to dissection
    - Worse prognosis if associated penetrating ulcer
  - **Penetrating atherosclerotic aortic ulcer**
    - Typically less problematic in abdominal than thoracic aorta
      - May result in intramural hematoma
    - Increased ulcer depth/diameter predict disease progression; significant aortic wall weakening
      - Consider endovascular/surgical intervention
      - Can lead to dissection/pseudoaneurysm/rupture
    - Increased rupture rate if symptomatic (38%)
      - Intervention for refractory/recurrent symptoms
  - **Symptomatic AAA**
    - Acute, severe, unrelenting back/abdominal pain
    - Ruptured aneurysm
- **Abdominal aortic stenotic/occlusive disease**
  - Symptomatic stenotic/occlusive disease
    - Claudication/rest pain/tissue loss
    - Unresponsive to medical treatment
    - Aortic occlusion usually requires open surgery
  - Ulcerated plaque with distal embolization
- **Traumatic aortic injury**
  - Penetrating/blunt trauma disrupting aortic wall

Contraindications

- **General**
  - Uncorrectable coagulopathy
  - Severe renal insufficiency
    - Nondialysis-dependent
    - May consider alternative contrast agent (e.g., CO_2)
  - Prior history of cholesterol embolization syndrome
    - High recurrence rate with any intervention
  - Systemic infection
    - Risk of infection of covered stent (rare)
- **AAA**
  - Poor aneurysm anatomy/morphology for EVAR
    - Short, wide, excessively angled AAA neck
    - Circumferential thrombus/calcification in neck
    - Juxtarenal aneurysm
  - Inadequate iliac artery access for EVAR
    - Highly calcified/small-caliber/tortuous vessels
- **Acute aortic syndromes**
  - Asymptomatic aortic dissection/intramural hematoma/penetrating atherosclerotic ulcer
    - May be medically managed; requires close clinical/imaging surveillance to assess for progression
  - Hemodynamically unstable patient
    - Requires careful patient selection
      - Good outcomes with endovascular repair when possible; may require open surgical conversion
- **Abdominal aortic stenotic/occlusive disease**
  - Bulky, heavily calcified plaque (e.g., "coral reef")
    - Surgical endarterectomy/bypass more optimal
  - Most aortic occlusions better treated surgically
    - Focal aortoiliac occlusions may respond to "kissing" stents if able to recanalize
      - Poorer long-term patency than surgery
- **Inflammatory aortitis**
  - Evidence of active disease
    - Systemic symptoms
      - Fever/arthralgia/myalgia
    - Laboratory abnormalities
      - Elevated erythrocyte sedimentation rate (ESR)
      - Positive C-reactive protein
  - Active disease may adversely affect revascularization

Preprocedure Imaging

- **CTA**
  - Excellent delineation of arterial anatomy/pathology
  - Characterization of target lesion(s)
  - Preprocedural aortic endograft planning
- **MRA**
  - Excellent delineation of arterial anatomy/pathology
    - Useful in acute/inflammatory/infectious processes

Getting Started

- Things to check
  - Clinical history and physical examination
    - Appropriate procedure indications
    - Comprehensive vascular evaluation
      - Detailed pulse examination/Doppler evaluation
    - Review prior endovascular/surgical interventions
      - May influence choice of optimal access
    - Current medications
      - Any anticoagulants, antiplatelet agents, oral hypoglycemic agents, antihypertensives
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - Complete blood count (CBC)
      - Platelet count > 50,000/μL
    - Coagulation profile

    - International normalized ratio (INR) ≤ 1.5
    - Normal prothrombin time (PT), partial thromboplastin time (PTT)
  - Inflammatory markers
    - C-reactive protein
    - Erythrocyte sedimentation rate
- Limit oral intake: NPO for 8° prior to procedure
  - If moderate sedation/general anesthesia planned
  - Take any oral medications with water sip

- Medications
  - Heparin
    - Various intraprocedural administration regimens
      - Bolus dose of 2,500-5,000 U; followed by infusion of 1,000 U/h
      - Loading dose of 50-100 U/kg; followed by continuous infusion of 15-25 U/kg/h
  - Vasodilator (e.g., nitroglycerin)
    - Typical bolus dose of 100 μg nitroglycerin
    - Prevents/treats catheter-induced vasospasm
  - Clopidogrel
    - May electively give loading dose before procedures involving stenotic/occlusive disease
      - 300 mg minimum loading dose
    - Continue maintenance dose post procedure
      - 75 mg daily dose for 4-6 weeks minimum
- Equipment list
  - Catheters/sheaths
    - Vascular access sheath
      - Permits catheter exchanges as necessary
      - Reduces local complications at access site
      - Various available sheath sizes; choice depends on catheter/device used for procedure
    - Flush catheter (e.g., pigtail, Omni Flush)
    - Selective catheters (e.g., Kumpe, multipurpose angled, Cobra)
    - Specialty catheters
      - Angioplasty (PTA) balloon catheter
  - Guidewires
    - Initial "starting" 0.035" guidewire (3-J tip)
    - Angled or straight-tipped hydrophilic guidewire
      - Useful for crossing stenosis/occlusion
      - Useful for selective arterial catheterization
    - Stiff guidewire
      - e.g., Amplatz, Lunderquist, Rosen
      - Provides stability when advancing devices
  - Stents
    - Covered
      - Balloon-mounted: Currently available stents undersized for typical abdominal aorta
      - Self-expanding: Large caliber of abdominal aorta typically requires aortic endograft components
      - Aortic endografts
    - Noncovered
      - Balloon-mounted: Typically more precise placement; requires large caliber stent [e.g., Palmaz XL (Cordis; Miami Lakes, FL)]
      - Self-expanding: Currently available stents undersized for typical abdominal aorta

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Typically common femoral artery access used
  - May sometimes require brachial artery access
    - Smaller caliber artery; problematic if large-caliber device needed for intervention
    - Severe aortic stenosis may require flush catheter placed via brachial access for initial DSA
      - Intervention subsequently performed from combined femoral/brachial access

Procedure Steps

- **General**
  - Sterilely prepare/drape intended access site
  - Administer 1-2% lidocaine local anesthesia
  - Obtain arterial access
  - Place appropriately sized vascular access sheath
    - Size based on intended device for intervention
  - Introduce catheter; obtain DSA images
    - Severe aortic stenosis may require negotiating stenotic lumen with selective catheter/guidewire
      - May need concurrent brachial access
  - Analyze DSA images to delineate anatomy
    - Determine appropriate intervention/device
  - Administer heparin prior to intervention
- **Acute aortic syndromes**
  - When intervention indicated, typically managed by aortic endograft placement or surgery
    - Type B dissections involving abdominal aorta may require other endovascular interventions
      - Proximal entry closure using endograft
      - Bare metal stent implantation in true aortic lumen or aortic branch vessels
      - Fenestration of dissection flap: Decompress true lumen by creating reentry tear to equilibrate blood pressure between true and false lumens
- **Abdominal aortic stenotic/occlusive disease**
  - Stenosis location/relationship to branch vessels major determinant of optimal treatment
    - Atherosclerotic stenosis near aortic bifurcation usually treated with "kissing" iliac artery stents
    - Treat infrarenal aortic stenosis with PTA/stent
      - Need adequate distance from branch vessels to avoid compromising arterial origins
      - Balloon inflation/stent deployment can displace atheroma into renal/mesenteric artery orifices
      - May need adjunctive renal/mesenteric artery stent(s) to maintain/restore patency
      - Endarterectomy/surgical bypass if suboptimal anatomy for endovascular intervention
    - Treat juxtarenal aortic stenosis with open surgery
  - Ulcerated plaque with distal embolization
    - Bare/covered stent placement to trap underlying pathogenic atherosclerotic lesion
      - Somewhat controversial; usually indicated only for macroemboli; also treated surgically
      - Not indicated for cholesterol embolization; diffuse process with no single discrete lesion
  - Inflammatory stenosis (e.g., Takayasu aortitis)

    - May require multiple prolonged balloon inflations
      - Avoid overdilatation of stenosis; risk of rupture
    - If intervention is needed, PTA is traditional choice
      - Higher restenosis rate than atherosclerosis; may be related to persistent inflammation
      - Some advocate primary stenting/covered stents
    - If renal artery involvement also present, renal artery angioplasty also indicated
- **Traumatic aortic injury**
  - Endovascular aortic repair with endograft may stabilize disrupted aortic wall/contained rupture

Alternative Procedures/Therapies

- Surgical
  - Revascularization, resection, bypass, endarterectomy
- Other
  - Abdominal aortic stenotic/occlusive disease
    - Medical management/exercise regimen (claudicants)
  - Acute aortic syndromes
    - If asymptomatic or diagnosed solely by imaging
      - Medical management/blood pressure reduction
      - Close clinical/imaging surveillance important
  - Inflammatory aortitis
    - Corticosteroid administration
    - Additional immunosuppressive agents
      - e.g., cyclophosphamide/methotrexate
    - Experimental antitumor necrosis factor agents

OUTCOMES

Complications

- Most feared complication(s)
  - Vessel rupture
    - Higher incidence in inflammatory stenosis because of thickened noncompliant arterial wall
      - Avoid overdilatation/oversized PTA balloon
  - Macro-/microembolization during DSA/intervention
    - Rare: Estimated clinical incidence of 0.15%
  - Branch vessel occlusion during PTA/stenting
    - Atheroma/thrombus may be displaced into origins of adjacent renal/mesenteric arteries
      - May require branch vessel stenting for rescue
- Immediate/periprocedural complication(s)
  - Arterial dissection/thrombosis
  - Access site complications
    - Hematoma, pseudoaneurysm, iatrogenic arteriovenous fistula formation
- Delayed complication(s)
  - Contrast-induced nephropathy
  - Aneurysm-related complications
    - EVAR device-related complications
      - Type I/III/IV endoleak
    - Type II endoleak causing AAA sac expansion
  - Stenotic-/occlusive-related complications
    - Device-related complications
      - Stent fracture with thrombosis/occlusion
    - Neointimal hyperplasia
      - In-stent stenosis/thrombosis

Expected Outcomes

- **Atherosclerotic stenosis/ulcerated plaque**
  - High stenting success rates in appropriate lesions
  - Elimination of stenosis-related buttock/lower extremity claudication
  - Prevention of distal embolization from ulcerated plaque
- **Acute aortic syndromes**
  - **Intramural hematoma** or **penetrating ulcer**
    - Stabilization of weakened aortic wall by means of endograft placement
      - Prophylaxis to prevent potential saccular aneurysm formation, aortic rupture or dissection
  - **Aortic dissection**
    - Clinical improvement of malperfusion symptoms following endograft placement &/or fenestration
- **Inflammatory aortitis**
  - High failure rate of vascular interventions for Takayasu aortitis (open and endovascular)
    - However, PTA/stent/surgical bypass may be necessary for stenotic/occlusive disease

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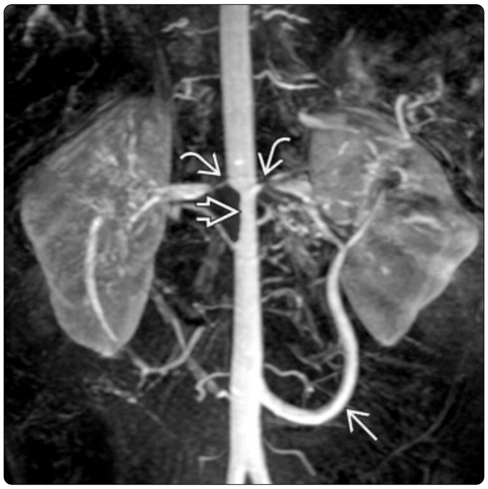
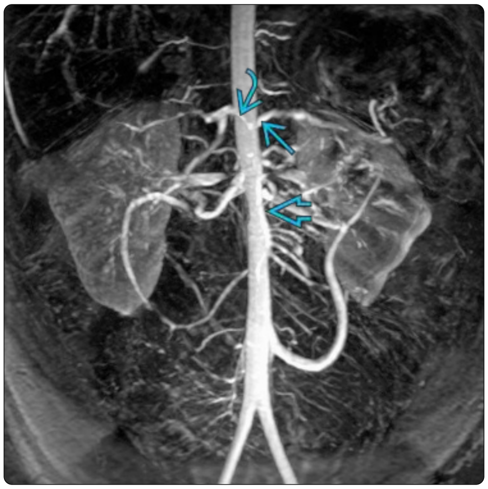
Aortic Coarctation Syndromes: Neurofibromatosis

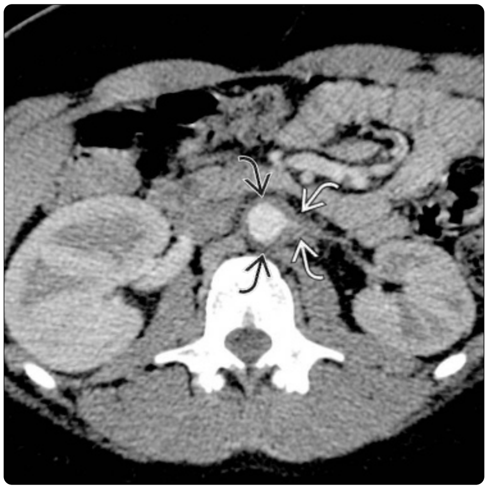


Aortic Coarctation Syndromes: Neurofibromatosis

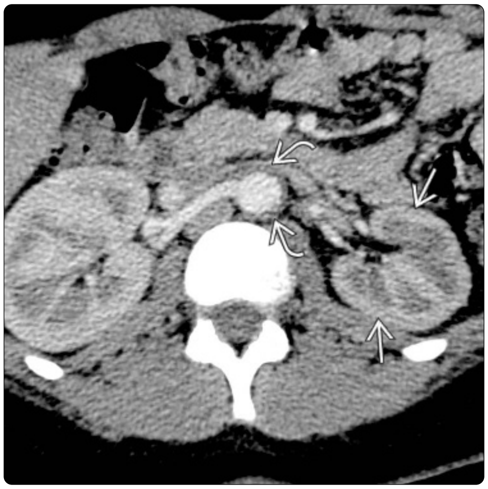


(Left) *MRA in an 18 year old with neurofibromatosis shows severe renal artery → and pararenal aorta ⇨ stenoses. The inferior mesenteric artery (IMA) → is enlarged, suggesting it contributes to a larger vascular territory than the descending colon.* **(Right)** *3D MRA shows a small superior mesenteric artery ⇨, likely from a proximal stenosis, and explains the enlarged IMA, as it provides collateral supply to the bowel. The hepatic ↷ and splenic → arteries are stenotic. Neurofibromatosis typically has a pararenal distribution, as in this case.*

Inflammatory Aortitis: Takayasu Arteritis

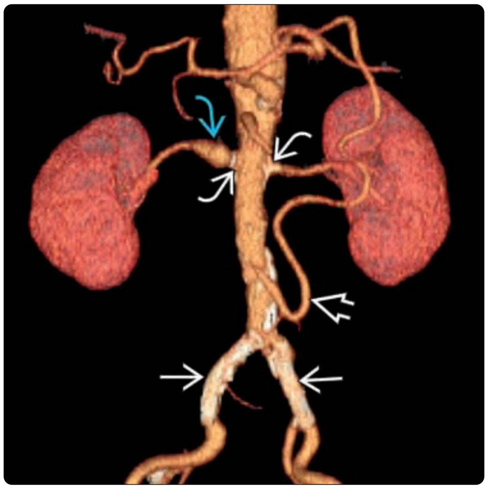


Inflammatory Aortitis: Takayasu Arteritis

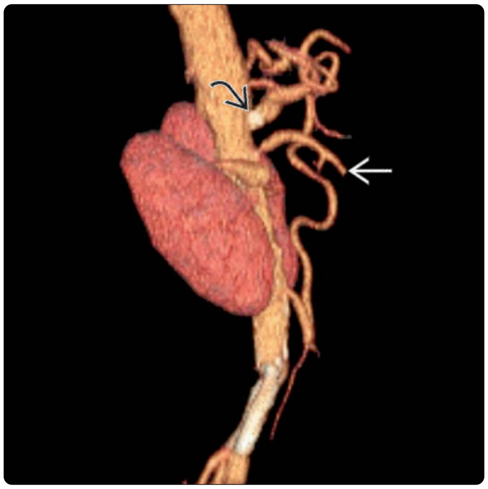


(Left) *Axial CECT in a 32-year-old woman with weight loss, abdominal pain, and hypertension shows a thickened abdominal aortic wall ↷. The process also narrows the left renal artery origin →. The appearance, location, and age are consistent with Takayasu arteritis.* **(Right)** *More caudal CECT also shows aortic wall thickening ↷. The left kidney is small →, as a result of chronic arterial insufficiency. Symptomatic stenoses can be angioplastied if necessary, but not during the active inflammatory phase.*

Inflammatory Aortitis: Takayasu Arteritis



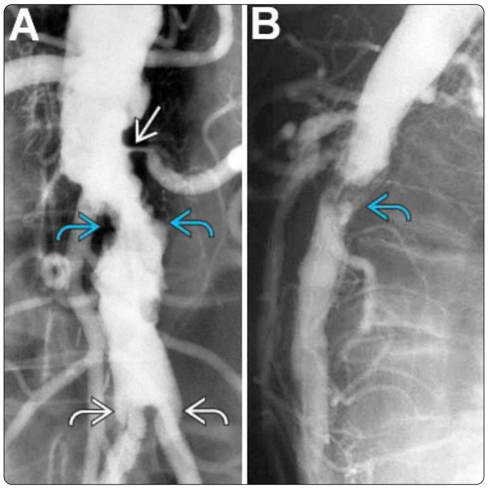
Inflammatory Aortitis: Takayasu Arteritis



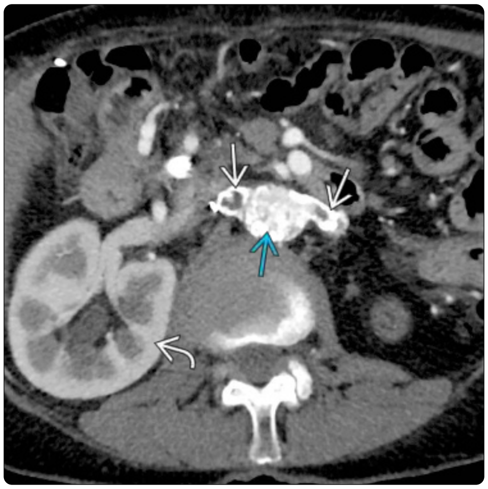
(Left) *3D CECT reformation in another patient with Takayasu arteritis shows multiple areas of involvement and evidence of prior interventions. Stents are seen in both common iliac arteries → and in both renal arteries ↷. There is poststenotic right renal artery dilatation ↷. The IMA ⇨ is markedly hypertrophied.* **(Right)** *Lateral 3D reformation shows a celiac artery stent ↷ and that the distal SMA is occluded →, explaining the enlarged IMA. Symptomatic stenoses may be treated with PTA, but stenting may be needed for refractory lesions.*

(Left) *(A) AP and (B) lateral abdominal aorta catheter angiography shows extensive and very irregular stenoses ⇨ of the pararenal aorta, with a severe left renal artery stenosis ➡. There has been prior aortobifemoral bypass ➡ surgery.* **(Right)** *Axial surveillance CECT 4 years later shows exuberant calcified plaque ⇨, almost obliterating the aortic lumen at renal artery level, causing occlusion of both renal arteries ➡. The right kidney ➡ enhances because there has been interval surgical placement of a hepatorenal bypass graft.*

"Coral Reef" Aortic Plaque

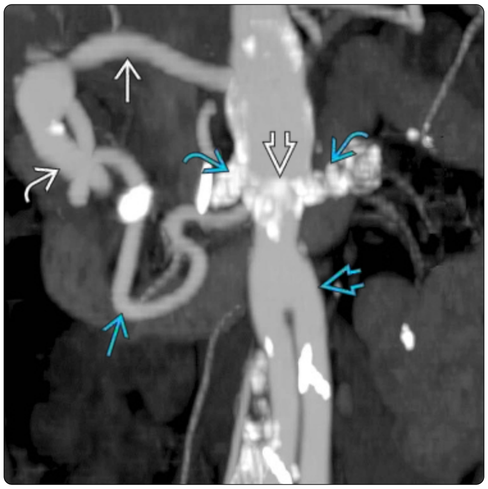


"Coral Reef" Aortic Plaque

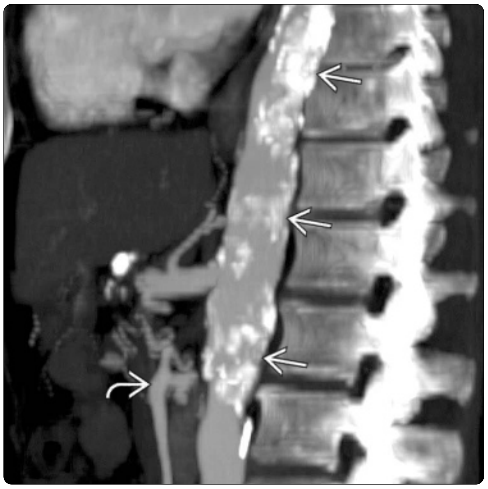


(Left) *Coronal 3D CECT reformation demonstrates a patent renal bypass graft ➡ arising from the hepatic artery ➡; the caudal continuation is the gastroduodenal artery ⇨. "Coral reef" plaque ➡ in the mid aorta, extends ⇨ into the occluded renal arteries. The aortobifemoral graft ⇨ is patent.* **(Right)** *Sagittal 3D reformation shows the extensive nature of the heavily calcified "coral reef" plaque ➡ in the aorta. In addition to bilateral renal artery occlusions, the SMA origin is occluded and the artery fills distally ➡ via collaterals.*

"Coral Reef" Aortic Plaque Surveillance: CECT Imaging Evaluation

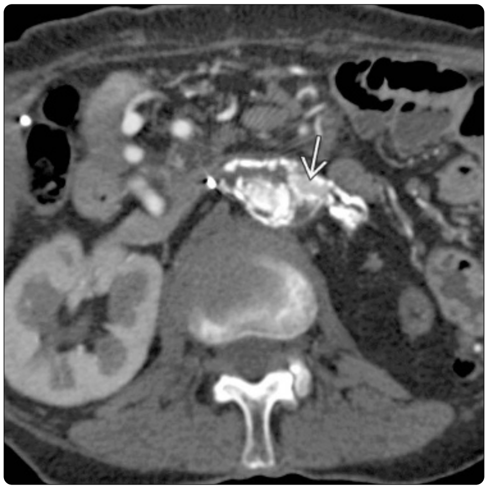


"Coral Reef" Aortic Plaque Surveillance: CECT Imaging Evaluation

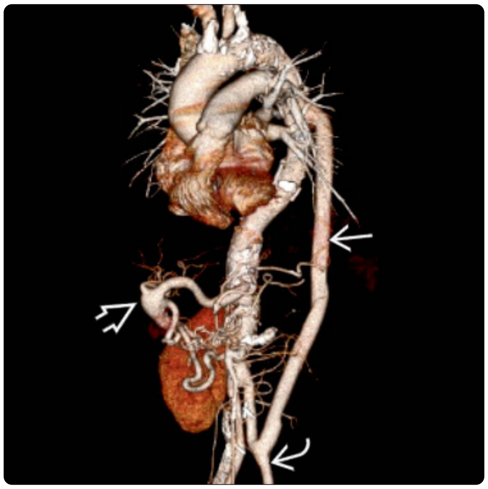


(Left) *Five years later, the patient developed rest pain. Axial CECT shows marked progression of disease in the mid aorta at the pararenal level, with only a small residual patent aortic lumen ➡.* **(Right)** *A surgical bypass ➡, from the thoracic aorta to the left limb ➡ of the prior aortobifemoral graft, relieved symptoms. The hepatorenal bypass ➡ and visceral arteries remain patent. "Coral reef" plaque is very aggressive; it may initially respond to an endovascular intervention but typically requires surgery eventually.*

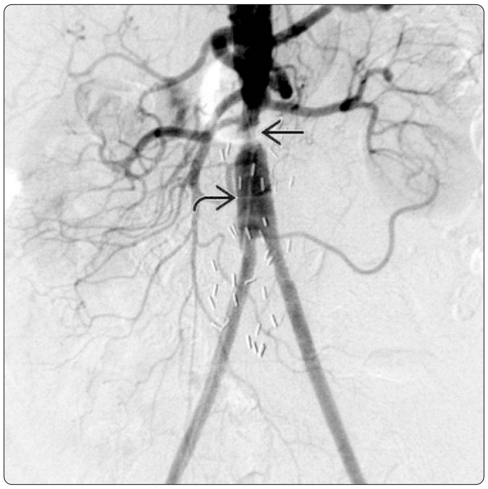
"Coral Reef" Aortic Plaque Surveillance: Disease Progression by CECT Evaluation



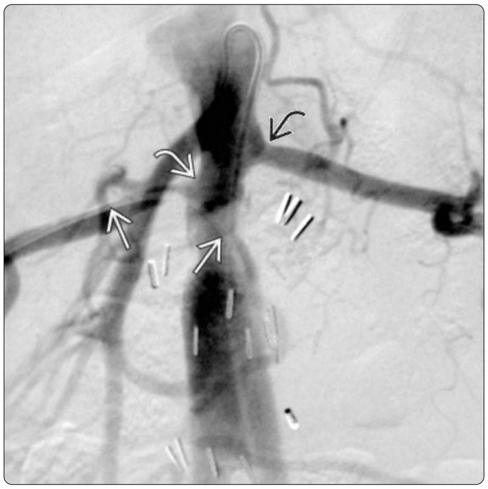
"Coral Reef" Aortic Plaque Surveillance: Disease Progression by CECT Evaluation



Anastomotic Aortic Stenosis

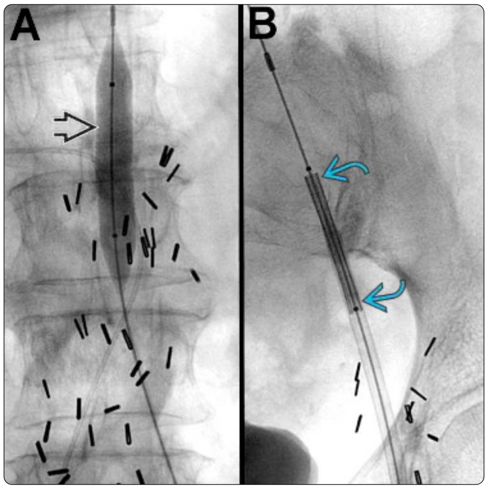


Anastomotic Aortic Stenosis

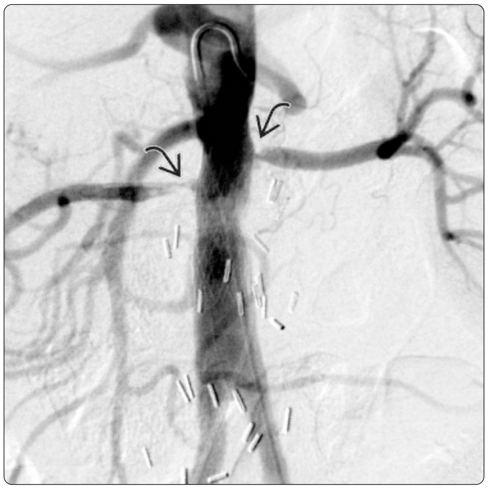


(Left) *A patient with an aortobifemoral bypass for atherosclerotic occlusive disease presented years later with new bilateral lower extremity claudication. DSA shows a severe stenosis → at the anastomosis of the bypass graft ↷ to the native aorta.* **(Right)** *DSA shows the right renal artery ➦ originates from the stenosis, while the left renal artery ↷ arises higher. Before treating the stenosis, a catheter ➡ was placed in the right renal artery to protect it from occlusion by any displacement of atheroma by angioplasty.*

Treatment of Anastomotic Aortic Stenosis: Intravascular Stent Placement

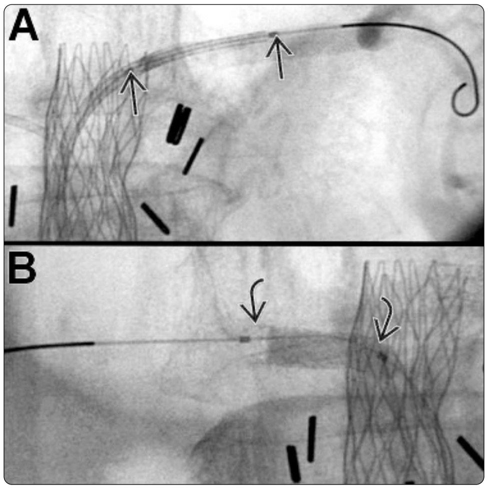


Treatment of Anastomotic Aortic Stenosis: DSA After Intravascular Stent Placement

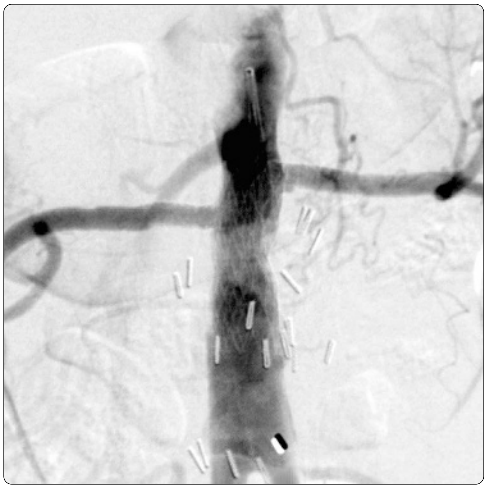


(Left) *(A) Via a left femoral artery access, PTA of the stenosis was performed with a 10-mm diameter, high-pressure balloon ⇨ using prolonged inflation. (B) After PTA, Palmaz stent ↷ was mounted on an 18-mm diameter, high-pressure balloon and was introduced via left femoral artery sheath.* **(Right)** *Stent was deployed with the upper end immediately below the left renal artery and the distal end terminating well above the graft bifurcation. Deployed stent caused stenoses ↷ in both renal arteries.*

Treatment of Anastomotic Aortic Stenosis: Management of Renal Artery Stenoses

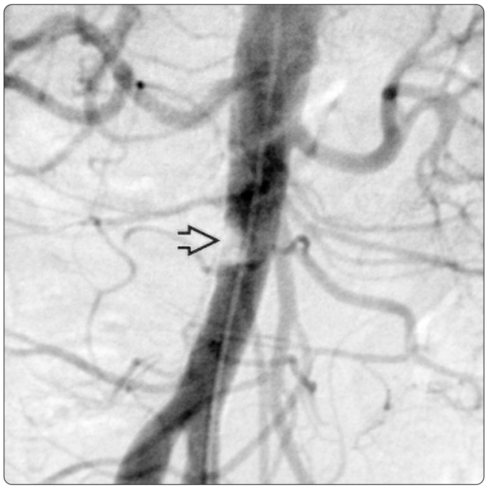


Treatment of Anastomotic Aortic Stenosis: Management of Renal Artery Stenoses

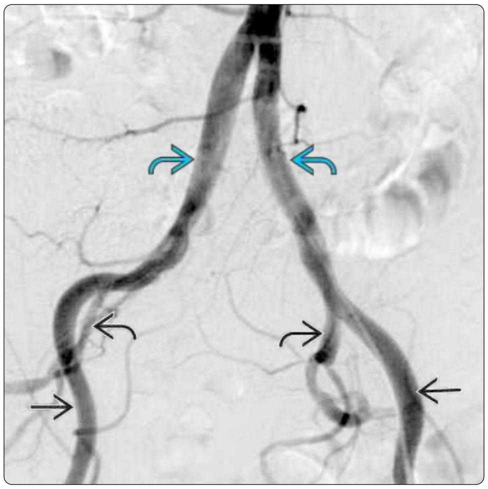


(Left) *(A) After catheterizing the left renal artery, a balloon-mounted stent → was deployed across the stenosis using a guiding catheter. (B) After left renal artery stent placement, the protective catheter was removed from the right renal artery and the orifice was catheterized through the stent interstices. This was followed by placement of a balloon-mounted stent ↷ across the interstices and the stenosis.* **(Right)** *DSA following aortic and renal artery stent placements shows elimination of all stenoses.*

(Left) *This patient underwent angiography for acute right leg ischemia. Aortogram shows an eccentric infrarenal aortic filling defect ⇨ causing a moderately severe stenosis. The filling defect has ill-defined, irregular margins and was felt to likely represent an ulcerated atherosclerotic plaque with adherent thrombus.* **(Right)** *Pelvic DSA shows normal anatomy, with patent common ↪, internal ↪, and external iliac → arteries and no stenoses. More importantly, there are no intraluminal filling defects to suggest embolic disease.*

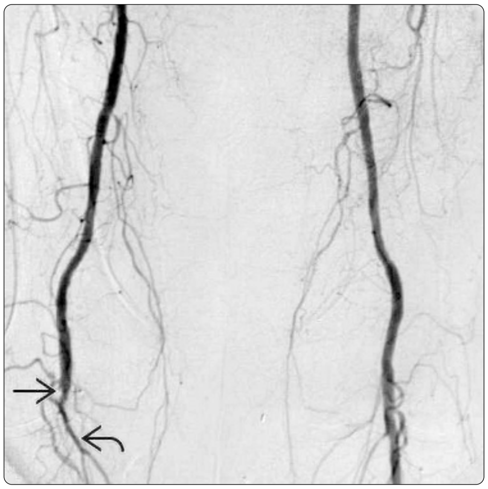


Ulcerated Aortic Plaque

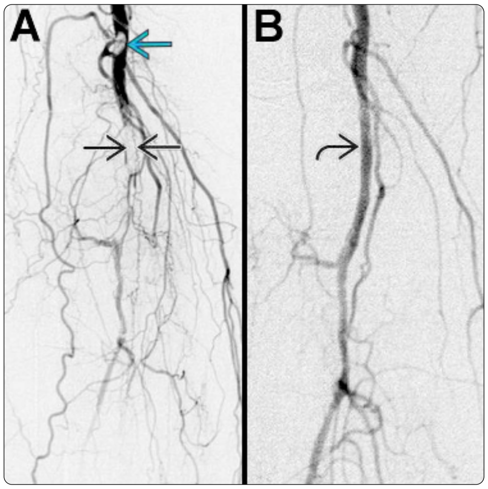


Ulcerated Aortic Plaque

(Left) *DSA evaluation of the superficial femoral and popliteal arteries shows normal left-sided anatomy. There is abrupt termination of the popliteal artery → at knee level, with filling of a collateral vessel ↪.* **(Right)** *(A) DSA after antegrade access to the right popliteal artery shows an intraluminal filling defect → and a distal tram-track sign → in the below-knee popliteal artery, consistent with acute embolic occlusion. (B) Catheter-directed thrombolysis with tissue plasminogen activator restored patency ↪.*

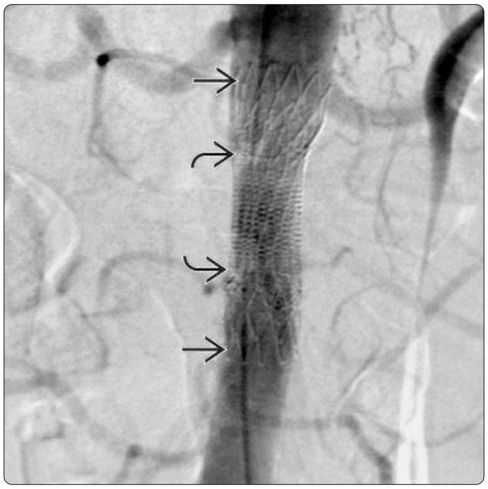


Ulcerated Aortic Plaque: Distal Embolization

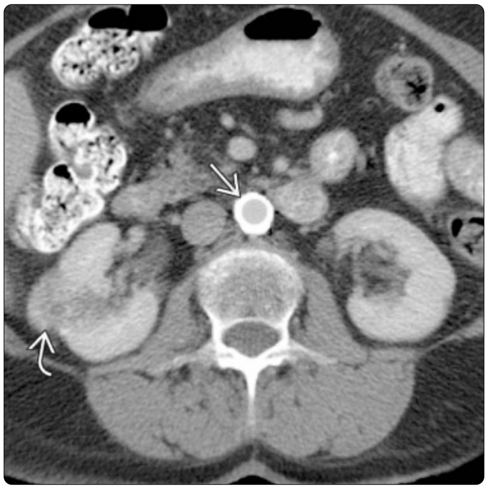


Ulcerated Aortic Plaque: Distal Embolization

(Left) *Due to concern that the plaque would be a continued source for distal embolization, it was elected to exclude the plaque. A self-expanding stent ↪ was placed, but as it had inadequate radial force to totally exclude the plaque, a balloon-mounted Palmaz stent → was also placed, excluding the plaque and eliminating the stenosis.* **(Right)** *Axial CECT shows satisfactory stent position ➡ and patency. Both kidneys enhance normally, with note made of a right renal mass ↪. There were no further embolic events.*

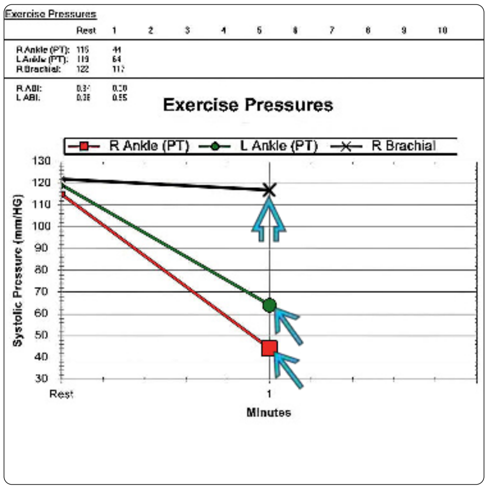


Ulcerated Aortic Plaque: Treatment

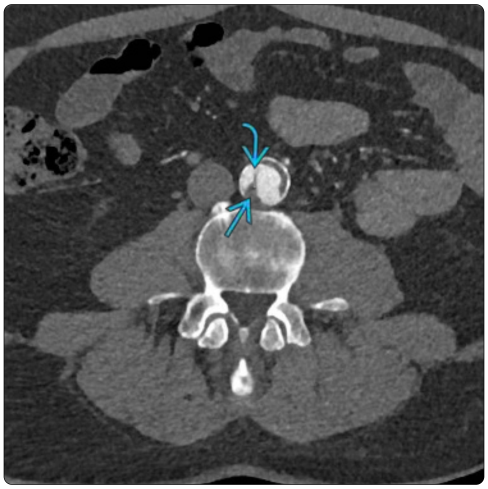


Ulcerated Aortic Plaque: CT Surveillance

Aortic Stenosis Causing Lower Extremity Claudication: Exercise ABIs

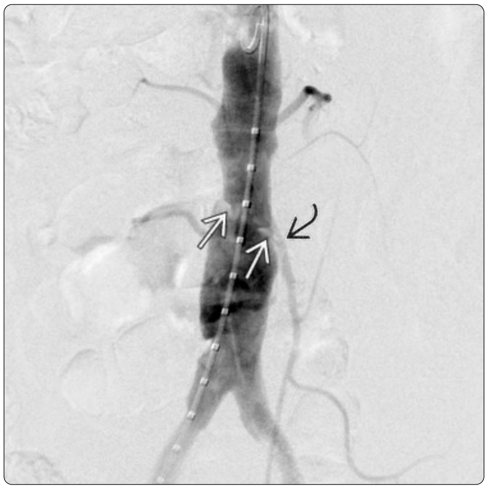


Aortic Stenosis Causing Bilateral Lower Extremity Claudication: CECT

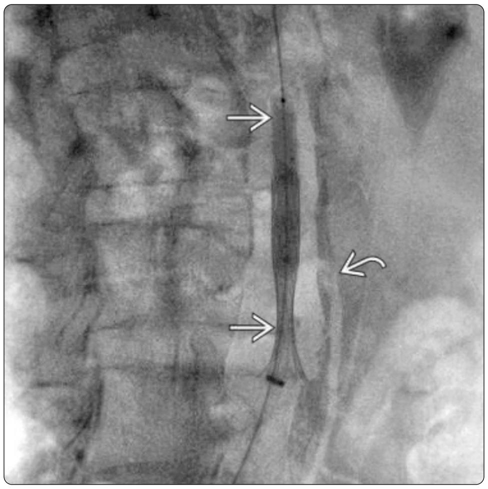


(Left) *Noninvasive US ankle:brachial index evaluation of the lower extremities during exercise in a patient with bilateral lower extremity claudication shows systolic pressure drops in the right and left ABIs →. The normal response should be an increase in the systolic pressures. Note that the brachial pressure → does not drop.* **(Right)** *Axial CECT shows an irregular lumen of the lower abdominal aorta with a cleft-like stenosis → and laminar thrombus →. This was felt to be the etiology for the patient's symptoms.*

Aortic Stenosis Causing Bilateral Lower Extremity Claudication: DSA

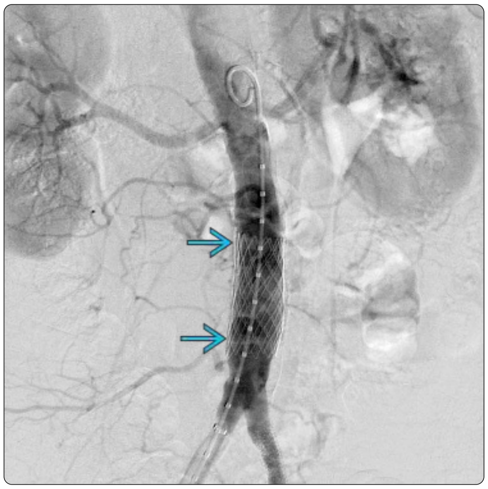


Aortic Stenosis Causing Bilateral Lower Extremity Claudication: Stent Placement

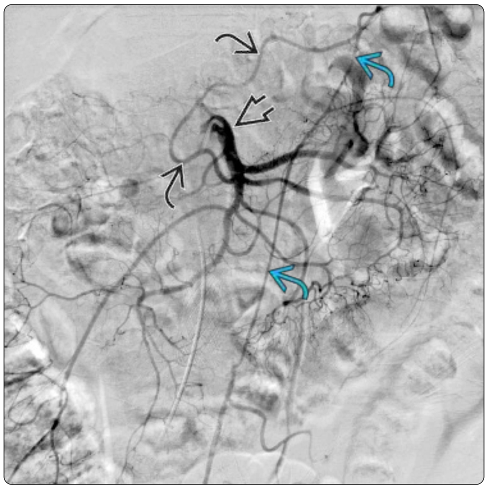


(Left) *DSA of the infrarenal aorta confirms an oblique cleft-like stenosis ➡ compromising the diameter of the aortic lumen at approximately the level of the inferior mesenteric artery ↷.* **(Right)** *Using an image-overlay from a previously obtained anterior oblique DSA, a balloon-mounted stent ➡ was introduced from a right transfemoral approach, and was positioned so that it was centered at the level of the inferior mesenteric artery ↷. This positioning insured that the stent would span the stenosis.*

Aortic Stenosis Causing Bilateral Lower Extremity Claudication: DSA After Stenting



Aortic Stenosis Causing Bilateral Lower Extremity Claudication: SMA Arteriogram



(Left) *DSA after deployment of the balloon-mounted stent shows ideal stent position → in the infrarenal aorta, with a widely patent lumen. Note, however, that after stenting, the inferior mesenteric artery no longer fills in an antegrade fashion.* **(Right)** *DSA of the superior mesenteric artery ⇒ shows filling of the middle colic artery ↷ and of the ascending branch ↷ of the left colic artery, in retrograde fashion. This confirms adequate perfusion of the descending colon. The patient's claudication resolved after stenting.*

Upper Gastrointestinal Hemorrhage

KEY FACTS

TERMINOLOGY

- Hemorrhage in territory supplied by celiac artery; boundary is celiac artery-superior mesenteric artery (SMA) watershed zone, near ligament of Treitz
- ~ 375,000 patients receive treatment for arterial GI hemorrhage in USA annually [> 80% have upper gastrointestinal (UGI) source]

PREPROCEDURE

- No contraindication is absolute; risks of intervention should be weighted against risk of not intervening (mortality due to hemorrhage)
- Endoscopy for UGI hemorrhage is useful, even if operator unable to stop hemorrhage
  - Identification of location of hemorrhage allows for effective empirical embolization, even without obvious contrast extravasation on angiogram
- **Embolic agents**: Variety of embolization choices, some considered permanent (i.e., coils), while others temporary [i.e., Gelfoam (Upjohn, Kalamazoo, MI)]
  - However, coils may occasionally fail to arrest flow [when international normalized ratio (INR) is high] and Gelfoam occasionally may result in permanent vessel thrombosis
  - Other times, combination of embolization agents may be best option; in many cases, experienced operator's judgment is superior to available literature description

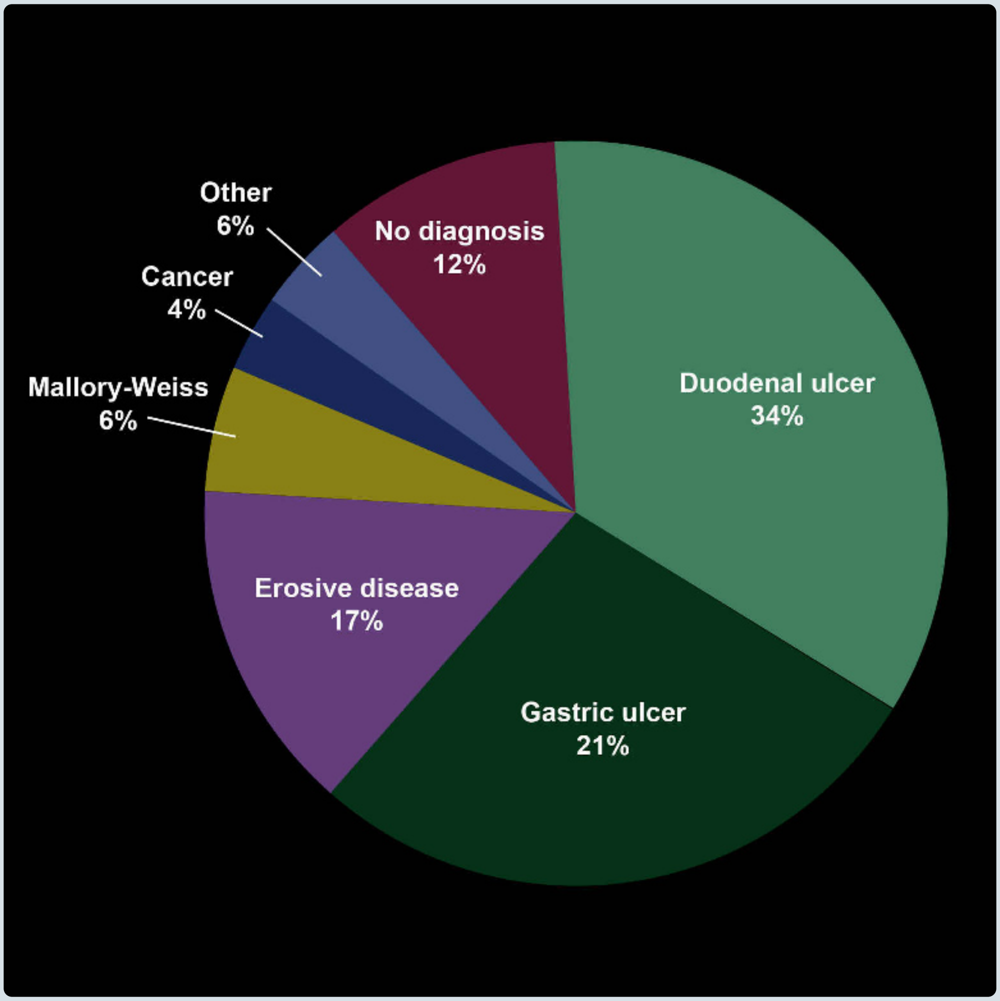
PROCEDURE

- Proper planning is crucial factor that contributes to success of intervention
- In most cases, review of existing imaging studies, history, signs, and symptoms reveals cause and site of hemorrhage

POST PROCEDURE

- If hemorrhage is identified on angiogram, success rate is 70-90%, depending on etiology

Causes of Upper Gastrointestinal Hemorrhage



In the Western world, the most common cause of upper gastrointestinal (UGI) arterial hemorrhage is peptic ulcer disease. Indeed, duodenal ulcer, gastric ulcer, and gastritis comprise nearly 75% of all UGI hemorrhage causes. Smoking, alcohol, steroid use, prolonged hospitalization, and Helicobacter pylori infection are the most common underlying causes of peptic ulcer disease.

TERMINOLOGY

Definitions

- **Upper gastrointestinal (UGI) hemorrhage**
  - Hemorrhage in territory supplied by celiac artery
  - Boundary between UGI and lower gastrointestinal hemorrhage
    - Celiac artery-superior mesenteric artery (SMA) watershed zone
    - Near ligament of Treitz
  - Some hemorrhages can be supplied by both celiac artery and SMA
    - Specifically 2nd and 3rd portions of duodenum
  - Upper and mid esophagus is supplied by short aortic branches
  - Lower esophagus is supplied by left gastric artery
- Epidemiology
  - ~ 375,000 patients receive treatment for arterial GI hemorrhage in USA annually
    - > 80% have UGI source
  - Prior to introduction of endoscopic/endovascular treatments, mortality was 25%
  - Since introduction of endoscopic/endovascular treatments, mortality has dropped to 5%
- Causes of UGI hemorrhage
  - ~ 70% of UGI hemorrhage are due to gastric or duodenal ulcer disease of erosive gastritis/duodenitis
  - Secondary causes of UGI hemorrhage
    - ~ 6% Mallory-Weiss tear
    - ~ 4% cancer
    - ~ 20% other

PREPROCEDURE

Indications

- Clinical evidence for arterial UGI hemorrhage
  - Hypotension
  - Tachycardia
  - Transfusion requirement
  - Pressor requirement
  - Hematemesis
  - Melena
  - Hemobilia (in patients with percutaneous biliary tube or biliary endoscopic interventions)
  - Clinical/surgical history (e.g., recent hepaticopancreaticobiliary surgery)
- Imaging evidence for UGI arterial hemorrhage
  - Endoscopic diagnosis
  - CT angiogram (becoming important 1st-line study)
  - Tagged RBC study
  - Ultrasound [especially in case of pseudoaneurysm (PSA)]

Contraindications

- No absolute contraindications
  - Risks of intervention must be weighed against risk of not intervening (mortality due to hemorrhage)
- Relative contraindications
  - Uncorrectable bleeding diathesis
  - Allergy to contrast (premedicate)
    - If urgent, consider general anesthesia for airway protection
  - Active infection; if elective and anticipate hardware implantation (covered stent, coils), may delay intervention for antibiotic treatment
    - Risk of stent/coil bacterial seeding is extremely rare, and urgent intervention should not be delayed
  - Prior surgery with altered vascular anatomy
    - Surgical vascular ligation may increase risk of ischemia after embolization
    - UGI territory enjoys rich collateral supply that minimizes risk of ischemia
  - Renal insufficiency
    - CO_2 angiography may be used to delineate vascular anatomy and reduce contrast load; however, it is not sensitive enough to identify hemorrhage

Preprocedure Imaging

- **Endoscopy**
  - Often 1st line of intervention
    - Useful even if operator is unable to stop hemorrhage
    - Identify location of hemorrhage allowing for effective empirical embolization, even without obvious contrast extravasation on subsequent angiogram
      - ☐ Example: Endoscopically seen duodenal ulcer allows for empirical embolization of gastroduodenal artery (GDA) even if no bleeding is noted on diagnostic angiogram
      - ☐ Example: Endoscopically noted bleeding source in fundus allows for empirical embolization of left gastric artery
  - Capsule endoscopy may be useful to guide embolization in small bowel if direct endoscopy is negative
- **CT**
  - CT angiography has proven to be very useful tool that can identify both location and cause of hemorrhage
    - In many centers, CT angiography has replaced nuclear scintigraphy as 1st-line diagnostic imaging study in stable patient
  - Even noncontrast CT can be helpful by revealing intra- or extraluminal blood (high-density fluid)
- **Nuclear scintigraphy**
  - May help localize most likely bleeding source/arterial territory
  - High sensitivity (90%) and specificity (80%)
  - However, nuclear scintigraphy is rarely useful for upper GI hemorrhage
    - Endoscopy will either treat hemorrhage or identify its location, negating utility of nuclear scintigraphy
  - Do not delay angiography for nuclear scintigraphy if there are clinical signs of active hemorrhage
    - All GI hemorrhage is intermittent
    - Hours-long delay may limit sensitivity of angiography
- **Ultrasound**
  - Hemorrhage after hepaticopancreaticobiliary surgery can be complicated by PSA
    - PSA of GDA
    - Intrahepatic PSA
    - Splenic artery PSA
  - Hemorrhage presenting after abdominal trauma similarly can be complicated by PSA
  - Ultrasound can diagnose PSA as well as confirm adequate treatment postembolization

- However, routine use of ultrasound as preembolization diagnostic imaging modality is not recommended unless there is specific need to exclude PSA

Getting Started

- Things to check
    - **Evaluate patient**
        - Assess urgency
        - Consent
            - If unconsentable, obtain consent from next of kin
            - If no next of kin is available, document emergent nature and proceed with angiography ± embolization
            - Discuss at minimum: Potential risk of ischemic bowel postembolization, acute renal insufficiency, inability to localize bleed
            - Patient/next of kin should be informed of possible need for repeat intervention(s)
        - Assess for adequate venous access
        - Appropriate fluid and blood resuscitation
        - Availability of blood products [packed red blood cells (PRBC), fresh frozen plasma (FFP), platelets]
        - Understand pressor requirements and titration parameters
    - **Evaluate clinical history**
        - May shed light on cause &/or location of hemorrhage
            - Recent Whipple surgery (GDA, PSA, or duodenal/pancreatic territory hemorrhage)
            - Prolonged violent vomiting spells (Mallory-Weiss tear)
            - Cholangiocarcinoma (hepatic artery erosion)
            - Cirrhosis/portal hypertension: (1) Venous hemorrhage and (2) splenic artery aneurysm
            - Vasculitis or use of medications that may cause vasculitis, etc.
            - Upper GI malignancy
        - Check allergies to any medications or other agents to be used (sedation, contrast agent, titanium)
        - Assess sedation vs. anesthesia
            - Aspiration risk, difficult airway, markedly obese, short neck, difficult to intubate, previous reaction to sedation, etc.
    - **Patient preparation**
        - Laboratory values
            - Evaluate comprehensive metabolic panel, complete blood count, and coagulation profile
            - If high creatinine, consider using CO_2 to reduce contrast load
            - Evaluate trends, not only single values; for example, hematocrit (Hct) of 30 is more onerous if previous value was 40 instead of 30
        - Special attention should be paid to coagulation profile
            - Anticoagulated blood does not clot, potentially rendering coil embolization ineffective
            - International normalized ratio (INR) < 1.8; if higher, may give FFP
            - Vitamin K takes longer to have effect on INR
            - Platelets > 50,000 (if lower, may transfuse platelets)
            - Values outside above guidelines are not absolute contraindications to intervention
            - Risk of nonintervention must be considered in decision-making process
            - For example, access sheath may be left in place until coagulation profile allows safe removal and should not in itself be reason to deny intervention
            - Large volume blood transfusions may affect coagulation profile
            - PRBC are anticoagulated with citrate phosphate dextrose formulations
            - Massive transfusion protocols automatically replenish clotting factors (FFP and platelets) in patients requiring large PRBC transfusions
    - **Team preparation**
        - If under anesthesia, communicate with anesthesia team intervention plan, risks, anticipated outcomes, and expected postoperative needs
        - Time out: Everyone must know plan
        - Team must be able to perform advanced cardiac life support (ACLS)
            - ACLS training saves lives
        - Team must be in effective communication with referring team and unit
        - There must be postembolization: (1) Treatment, (2) monitoring, and (3) potential reintervention plan
        - Equipment and supply (including resuscitation agents, crash cart)
- Medications
    - **Sedative agents**
        - Fentanyl/midazolam typically used for moderate conscious sedation
        - Propofol can be administered by those trained in deep sedation
        - General anesthesia may be necessary in unstable patients
            - General paralysis preferred over spontaneous respiration to eliminate motion artifact during angiography
    - **Peristaltic inhibitor**
        - Glucagon (1-mg IV)
            - Slows bowel peristalsis and mitigates misregistration artifact
            - Use with caution if history of diabetes
    - **Provocative agents**
        - Vasodilators: Allow for vasospasm prevention, more selective access, and potentially improve diagnostic accuracy of angiogram by provoking hemorrhage
            - Nitroglycerin 100 μg
            - Calcium channel blockers
        - Tissue plasminogen activator (TPA), 2 mg via selective catheter
            - Provoking hemorrhage with TPA can allow embolization in rare instances if territory of hemorrhage is known (from prior imaging) and catheter access is selective in that territory
            - Heparin can be given instead (probably less likely to provoke hemorrhage as it is not thrombolytic agent)
    - **Vasoconstrictor agent**
        - Vasopressin, reduces hemorrhage by generalized vasoconstriction
        - Continuous infusion

    - Rarely used because
      - High incidence of rebleeding
      - Potential systemic side effects (myocardial &/or bowel ischemia)
      - May require prolonged administration (days)
- Equipment list
  - **Sheaths**
    - Short 5-Fr vascular sheaths for uncomplicated cases
    - Longer, larger vascular sheaths can engage 1st-order target vessel (i.e., celiac or SMA) and allow for
      - Covered stent deployment
      - Stability in complicated cases
      - Rescue interventions in case of complications
  - **Catheters**
    - 5-Fr catheters of multiple shapes to allow access in variety of vascular anatomic variations
    - Microcatheters
      - Normal (if coil use is expected)
      - High flow (if glue or particle use is expected)
      - Proper microcatheter selection is important; coil use should be avoid with high-flow catheters; coil-pusher wire may become lodged between coil and catheter wall
  - **Wires**
    - Regular 0.035" for sheath, catheter access
    - Microwires
      - Large variety increases chances of successful target vessel access
      - Soft microwires allow for distal access in tortuous anatomy but provide poorer catheter trackability
      - Stiff microwires provide better catheter trackability but difficult to negotiate in complex vascular anatomy
  - **Embolic agents**
    - Variety of embolizations choices exist
    - Some considered permanent (i.e., coils), while others are temporary [i.e., Gelfoam (Upjohn, Kalamazoo, MI)]
      - However, coils may occasionally fail to arrest flow (when INR is high)
      - Conversely, Gelfoam occasionally may result in permanent vessel thrombosis
    - Combination of embolization agents may be best option
    - Experienced operator's judgment is superior to available literature description
    - **Coils**: By far most common embolization agent for GI hemorrhage
      - Introduced through either 5-Fr catheter (0.035", regular coils) or nonhigh-flow microcatheter (0.018", microcoils)
      - Metallic coils come in variety of sizes, shapes, and designs
      - As small as 1 x 2 mm straight, to upward of 20-mm coiled diameter
      - May be fibered (promote clotting), expandable gel coated, or bare
      - Pushable coils: Cannot be readily retrieved; pushed by wire or hand injected using saline syringe
      - Pushable coils: Reserved for end vessels where coil cannot be lost downstream
      - Retrievable coils: Can be partially deployed, retrieved, and redeployed
      - Retrievable coils: Used when there is high risk of shunting or nontarget embolization
      - Retrievable coils: Consider for arteriovenous fistula embolization, nonend vessel embolization, poor sheath/catheter stability
      - After measuring vessel diameter, oversize arterial coil by 20%, venous coil by 50% or more to ensure stability
      - Remember to shut "back door" in nonend vessel embolization to prevent retrograde flow and continued hemorrhage
      - Use snare (microsnare) to retrieve "lost" coil in nontarget embolized vessel; consider leaving lost coil behind if in small vessel (i.e., branch of hepatic artery)
      - Caution: High-flow shunting may allow "undersized" coil to shunt through and embolize distally (i.e., lungs)
      - Caution: Oversized coil may remain uncoiled, extending proximally out of intended target vessel
    - **Gelfoam slurry**
      - Used when hemorrhage is due to temporary condition
      - Risk for reflux and nontarget embolization if used in small vessels
      - May be used to complete stasis after incomplete coil embolization
      - Stasis is quick; inject very small amount and recheck for embolization
      - Gelfoam slurry preparation
      - Cut Gelfoam in small cubes (~ 1 mm each) and 1/2 fill 10-cc syringe
      - Depress plunger to remove air and compress Gelfoam, then fill syringe with contrast
      - Use 2nd syringe and 3-way stopcock to form slurry by vigorously pushing mixture between syringes
      - Partially close 3-way stopcock to make slurry thinner
      - Caution: Use only in end vessels
      - Caution: Avoid in cases where macroshunting is present
      - Caution: Consider "dead volume" of delivery catheter to prevent over embolization/Gelfoam reflux into nontarget vessel
    - **Liquid embolics**
      - **"Glue," N-butyl cyanoacrylate TRUFILL (Cordis; Bridgewater, NJ)**
      - Glue is mixed with radiodense lipiodol for opacity
      - Higher lipiodol:glue ratios (i.e., 8:1 by volume) polymerize more slowly, allowing more distal, small vessel embolization
      - Lower lipiodol:glue ratios (i.e., 1:1 by volume) polymerize very quickly: Best suited in high-flow system/small arteriovenous shunting to avoid nontarget embolization
      - Caution: Anything ionic (blood, saline, dirty gloves, etc.) precipitates polymerization clogging catheter/prematurely terminating procedure
      - **Onyx (ev3 Neurovascular; Irvine, CA)**

  - Not adherent to vessel wall, occludes by filling luminal space
  - 2 densities: 18 and 34, thinner and thicker, respectively
  - Edges polymerize while center remains liquid (lava-like filling of vessels)
  - Solvent is dimethyl sulfoxide
  - Rarely indicated for upper GI hemorrhage
  - Caution: Onyx sparks when cauterized (monopolar electrocautery), warn surgeons if surgery is planned
  - Caution: Consider "dead volume" of catheter to prevent overembolization and reflux into nontarget vessel
  - Caution: Prolonged contact of liquid embolic with catheter may result in catheter occlusion
  - Caution: Arteriovenous shunting can allow liquid embolics to bypass target, embolizing lungs or other nontarget vessels
  - Caution: Use preferentially in end vessels; avoid in cases where macroshunting is present
- **Particles**
  - Rarely indicated for GI hemorrhage
  - Relevant particle diameter ranges from 45-900 μm
  - Use only in end vessels
  - Particles arrest flow rather quickly; infuse small amount and recheck for stasis
  - Until recently, use of particles in GI system to be avoided for fear of ischemia
  - Recent studies show risk of UGI ischemia not as significant as previously held
  - Risk of ischemia is higher compared to coil or Gelfoam embolization
  - Use of smaller size particles and embolization of larger areas increases risk of ischemia
  - Caution: More dilute particle mixture takes longer to reach stasis; however, inadvertent nontarget embolization less likely to result in ischemia
  - Caution: Consider "dead volume" of catheter to prevent overembolization and reflux into nontarget vessel
  - Caution: Use preferentially in end vessels
  - Caution: Avoid in cases where macroshunting is present
- **Covered stents**
  - Low-profile covered stents allow nonembolic method of addressing hemorrhage
  - Advantageous when patency of injured vessels is desired
  - Long, stable sheath required to deliver stent with accuracy and perform necessary exchanges (balloon, stent, etc.)
  - Oversize stents by 10-20%
  - Deployment may be difficult in tortuous vessels
  - In UGI deployment, limited to large vessels (celiac, hepatic, or splenic) that can accommodate stents
  - Caution: Do not to cover important side branches/appropriately select stent length
- **Autologous blood clot**
  - Withdraw small amount of patient's blood
  - Allow exposure to partially clot and inject via catheter
  - Inexpensive and quick
  - Difficult to judge volume delivered
  - Effect is temporary; may recanalize quickly
  - Poor substitute for Gelfoam, which is inexpensive, longer lasting, and can be made opaque
  - Caution: Difficult to see during delivery
- **Vasopressin infusion**
  - Place catheter into target artery
  - Initiate vasopressin at 0.2 U/min
  - Repeat DSA at 20-30 min
  - If continued bleeding, increase rate by 0.1 U/min, then repeat DSA at 20-30 min
  - Increase infusion to maximum rate to 1-2 U/min
  - When hemorrhage controlled, secure catheter, reduce dose by 50%, continue infusion for 12-24 hr
  - Taper vasopressin off over 24-48 hr
  - Fallen out of favor: High recurrence rates, high complication rates, development of better alternatives
  - Vasopressin given systemically for pressure support: Resulting diffuse vasoconstriction may limit sensitivity of angiogram and limit catheterization
  - Caution: Systemic vasoconstrictive effect may result in organ ischemia
  - Caution: High risk of recurrent hemorrhage

PROCEDURE

Equipment Preparation

- Proper planning is crucial factor that contributes to success of intervention
  - In most cases, review of existing imaging studies, history, signs, and symptoms reveals cause and site of hemorrhage
  - In such cases, procedural steps must be determined prior
    - Plan access and access stability (length and size of sheath)
    - Plan sequence of diagnostic angiograms
    - Have catheters/microcatheters, wires, and embolization agents available
    - Anticipate possible complications and plan mitigating interventions
      - Snare for lost coil
      - Covered stent for surgical anastomotic rupture
      - Closure device usage or coagulopathic patients

Procedure Steps

- **Procedure-specific goals**
  - Angiography of SMA and celiac territories at minimum
  - Halt active bleed with embolization of feeding vessels
- **General**
  - Time out
  - Discuss plan and potential complications with interventional team and all other participating staff
  - Team must be prepared and able to provide ACLS
  - Ensure adequate pressure support and blood product availability
  - General anesthesia can provide extra layer of safety and allow interventionalist to concentrate on procedure but not absolute requirement

- **Access**
  - Selection of site
    - Most commonly right common femoral artery
    - Radial artery access allows for cephalad access, but longer catheters/microcatheters are necessary
  - Sterile preparation of access site
  - Ultrasound be be useful for access
    - Artery may be vasoconstricted due to hypovolemia and difficult to access
    - Avoid multiple punctures in patients with abnormal coagulation profile
- **DSA**
  - Directly engage artery suspected of hemorrhage
    - Typically reverse-curve catheter (Simmons I, SOS), rarely Cobra catheter
    - Utilize microcatheter for superselective engagement of suspected branches
      - High-flow microcatheter will improve diagnosis, but nonhigh-flow required when delivering some coils
  - Deliver 1-mg IV of glucagon to halt peristalsis/improve DSA imaging
  - Select high rate of frame (≥ 4 per sec)
  - Ask patient to hold breath or suspend respiration if patient paralyzed and ventilated
  - Power injection preferable to hand injections to generate adequate contrast density and filling of small/spasmed distal arteries
  - If hemorrhage is not seen, repeat in oblique views
  - If hemorrhage still not seen and strongly suspect hemorrhage from this artery, wait 10-15 min and repeat (hemorrhage is intermittent)
  - If hemorrhage still not seen and strongly suspect hemorrhage is from this artery, consider provocative angiogram
  - Aortogram is rarely useful and increases contrast load; perform only if there is specific indication
    - Suspicion of a direct aorto-enteric fistula
    - Upper or midesophageal hemorrhage
    - Difficulty engaging vessels due to variant anatomy
- **Intervention**
  - Once location of hemorrhage is identified, formulate intervention plan
    - Sheath length, type and shape, catheter length, type and shape, need for microcatheter/microwire, embolization method
      - Consider 5-Fr reverse-curve catheter in SMA/inferior mesenteric artery origin (e.g., Simmons I)
      - Consider nonhigh-flow microcatheter: Renegade 0.18 (Boston Scientific, Marlborough, MA) or Progreat 2.4 (Terumo, Somerset, NJ)
      - Consider GT Glidewire 45° or double curve (Terumo, Somerset, NJ), Transend or Fathom (Boston Scientific, Marlborough, MA)
    - Chose embolic agent, covered stent, or vasoconstrictor (typically coils)
    - Anticipate possible complications and plan how to avoid or address them
- **Termination**
  - When operator feels embolization is complete, perform hand-injected DSA
  - Do not power inject as this may cause coils or Gelfoam to dislodge
  - If there is still flow, deploy more embolics if there is room to do so
    - If no room to safely deploy more coils, small amount of Gelfoam may be useful
  - If there is still flow, wait 2-5 min and repeat hand injection
  - Slowed flow may result in thrombosis in time
  - Caution: It is last coil that causes problems
    - If there is adequate stasis, resist temptation to use "just 1 more" coil

Alternative Procedures/Therapies

- Radiologic
  - If variceal hemorrhage due to portal hypertension (GE varices, portal gastropathy)
    - Transjugular intrahepatic portosystemic shunt or
    - Balloon-occluded, retrograde transvenous obliteration
    - If peristomal varices, may try direct percutaneous variceal embolization
  - If PSA is accessible, percutaneous thrombin injection may be best option
    - Maybe especially useful for hepatic intraparenchymal PSA
- Surgical
  - Surgical exploratory laparotomy ± anatomic resection of bleeding source
    - May require extensive resection, with significant morbidity and mortality, especially in acute setting
      - Whipple for duodenal ulcer
      - Partial gastrectomy for gastric ulcer
    - Therefore, angiographic interventions must be exhausted before opting for surgery
- Other
  - Endoscopic management
    - Epinephrine injection/cautery/hemoclip
    - May be repeated ad lib
    - Even if unsuccessful, endoscopy can guide empirical embolization
    - Hemoclips mark focus of bleed but may dislodge in couple of days
  - Medical management
    - Fluid resuscitation and pressure support
    - Administration of blood products
      - Massive transfusion protocol balances relative need of blood products (RBC, platelets, FFP)
    - Correction of coagulation profile
    - Systemic vasopressin may mitigate hemorrhage by diffuse vasoconstriction

POST PROCEDURE

Things to Do

- Assign proper bed location, usually monitored bed
- Discuss procedure and expected outcome with floor team
- Discuss findings/plan with patient/patient's family
- Have plan for possible reintervention
- Sign-out plan to on-call interventional radiology team

- Monitor access site as many such patients are coagulopathic
- If coagulopathic or anticipate repeat intervention, leave sheath in place

Things to Avoid

- Do not fail to correct abnormal coagulation profile
    - High INR/low platelets may result in rebleeding despite proper embolization
- Do not assume hematochezia or melena within hours of successful embolization = rebleed
    - Judge efficacy by response to transfusion after embolization

OUTCOMES

Problems

- Factors that limit sensitivity of angiography
    - UGI hemorrhage is intermittent
        - Perform multiple AP, oblique views
        - Wait few minutes and repeat angiogram
        - Consider provocative angiogram
    - Vasoconstriction related to systemic pressure support (especially with vasopressin)
    - Poor digital subtraction of angiogram
        - Consider reviewing images in native view (without subtraction)
        - Peristalsis, give IV glucagon
        - Patient respiration, consider breath hold with general anesthesia
        - Patient motion, consider deeper sedation or general anesthesia
- Factors that limit efficacy of embolization
    - Unrecognized collateral blood supply
    - Incomplete embolization
    - Persistent coagulopathy
        - Correct INR and platelets before attempting repeat intervention
    - Vasodilatation after embolization may allow reperfusion of bleeding source

Complications

- Most feared complication(s)
    - Nontarget embolization/ischemia
        - Can occur with any type of embolization agent
        - Most "lost" coils can be retrieved but not other embolization agents
            - Attempt to retrieve only those which may cause problem
        - Exclude arteriovenous shunting before embolization
    - Bowel ischemia/infarction
        - Risk is much lower in UGI system, which enjoys rich collateral supply
            - Higher with particles, lower with coils
            - Be cognizant of previous surgery as vascular anatomy may be altered/diminished
- Immediate/periprocedural complication(s)
    - Access site complications
        - Bleeding/hematoma (could be retroperitoneal if high stick)
        - Arteriovenous fistula/PSA
    - Vasopressin infusion
        - Arrhythmias (bradycardia)
        - Antidiuretic hormone side effects (water retention, hyponatremia)
        - Coronary artery vasoconstriction/cardiac or systemic ischemia
- Delayed complication(s)
    - Contrast-induced nephropathy
        - Patients often have ≥ 1 recent CECT during current admission
        - Angiography and embolization can often deliver 100-cc to > 250-cc contrast
        - Intermittent UGI bleed may necessitate multiple angiograms to localize/treat
        - Patients are often hypovolemic from blood loss

Expected Outcome

- If hemorrhage is identified on angiogram, success rate is 70-90%, depending on etiology
    - Patients may have hematochezia, melena, or bloody gastric aspirate for few hours after procedure without continued or repeat bleed
    - Monitor for signs of rebleed
        - Hct response to transfusion
        - Hct stability after embolization (do not compare pre- and postembolization Hct)
        - Clinical signs of hemorrhage
- Clinical success (termination of bleeding)
    - Initial success may overestimate overall benefit
    - Bleeding reported to recur in many patients

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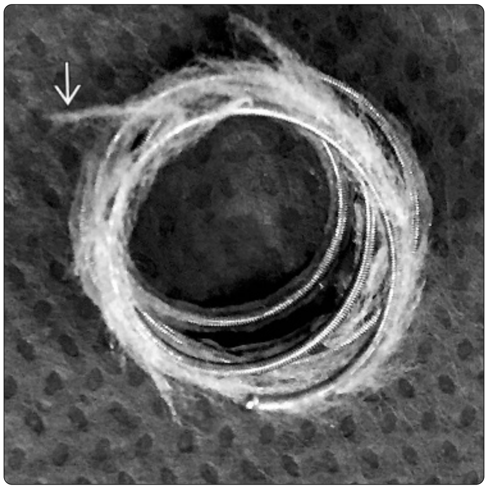
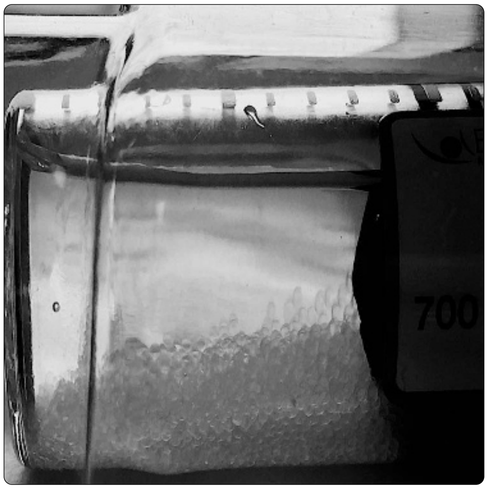
Embolic Agents: Coils

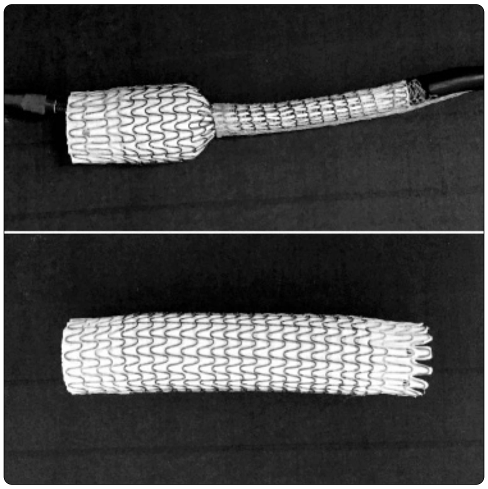


Embolic Agents: Particles in Suspension

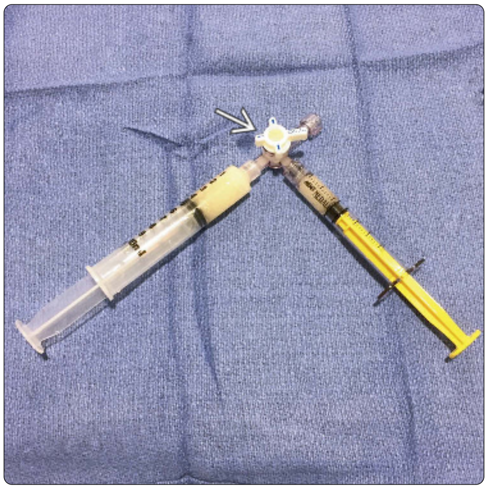


(Left) *Coils are the most frequently used UGI hemorrhage embolic device. Coil characteristics include: (1) Regular 0.035" vs. 0.018" microcoils, (2) fibered → vs. nonfibered, (3) detachable vs. pushable. Coil shape, length, and coiled diameter is elected based on the morphology of the target.* **(Right)** *Embolization particle size ranges from < 45-900 μm. Due to fears of bowel ischemia (possibly exaggerated), particles are used only in end vessels and only if other embolization methods are deemed unlikely to succeed.*

Embolic Agents: Covered Stents



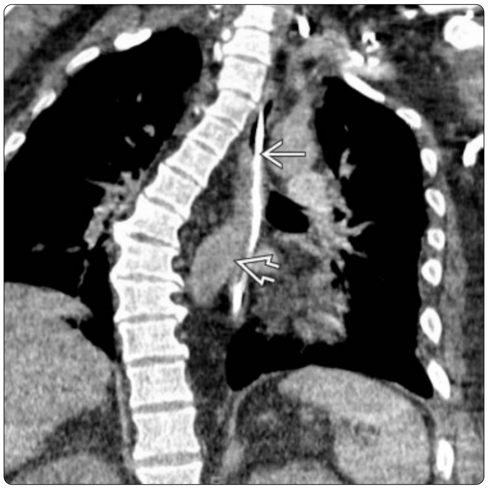
Embolic Agents: Gelfoam Slurry



(Left) *The introduction of low-profile (self- or more commonly used balloon-expandable) stents allows for effective treatment of certain types of hemorrhages while preserving flow in the injured vessel. A partially (upper) and fully deployed covered stent is shown in this figure.* **(Right)** *Preparation of Gelfoam slurry, a quick and inexpensive method for embolization, is shown. Two syringes are connected via a 3-way stopcock →. Vigorous agitation between the 2 syringes results in an injectable Gelfoam slurry.*

Embolic Agents: Gelfoam Slurry

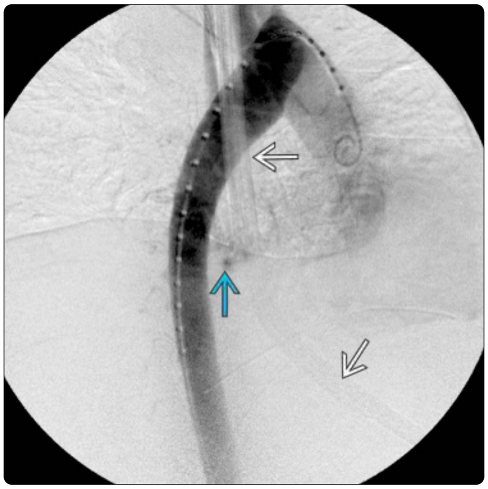
Aortoesophageal Fistula (Coronal CECT)



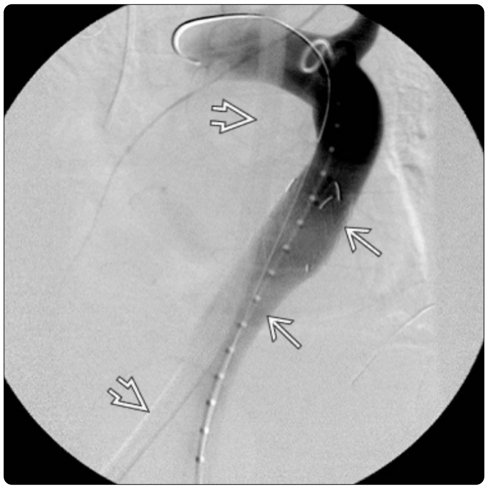
(Left) *Gelfoam slurry → embolization is a quick and inexpensive method of embolization. However, it requires experience to avoid over- or underembolization. It is considered a temporary embolization agent resorbed over time and, therefore, should be used where the vascular injury is likely to heal with 1-3 weeks.* **(Right)** *Severe hematemesis in a 59-year-old patient with prolonged nasogastric (NG) tube intubation → prompted a CT showing obliteration of the fat plane separating the esophagus and aorta ⇨.*

(Left) *This thoracic aortogram reveals acute extravasation from the midthoracic aorta → toward the nasogastric tube ➡.* **(Right)** *After thoracic stent-graft deployment ➡, the hemorrhage is no longer visualized. The injury was attributed erosion of the nasogastric tube ➡ into the aortic wall.*

Aortoesophageal Fistula: Initial Thoracic Aortogram

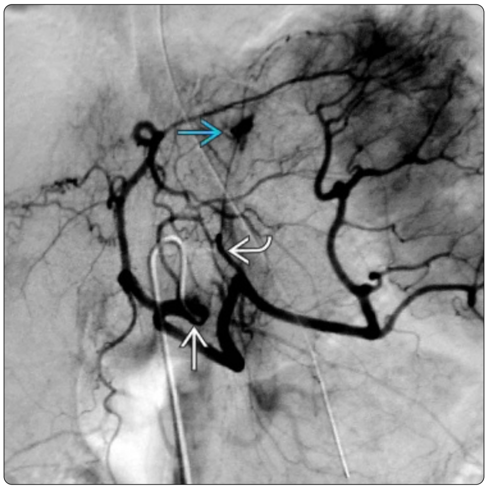


Aortoesophageal Fistula: Postendograft Repair (Thoracic Aortogram)

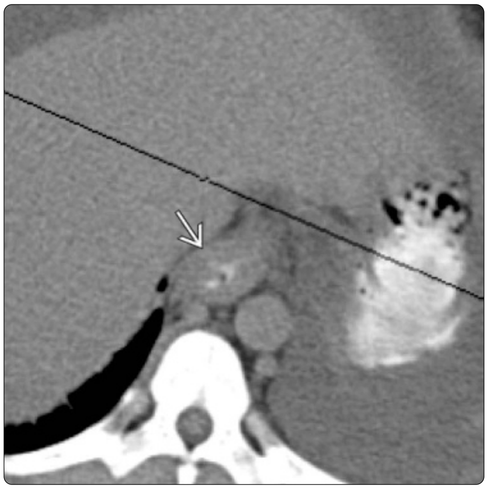


(Left) *A 31-year-old postpartum woman whose recovery was complicated by prolonged, violent vomiting with acute onset upper GI hemorrhage is shown. Celiac arteriogram ➡ reveals focal extravasation → at the gastroesophageal junction arising from the left gastric artery ↪. This is a Mallory-Weiss tear.* **(Right)** *A 45-year-old patient with several-day history of hematemesis is shown. The CT shows circumferential thickening of the distal esophageal mucosa ➡.*

Mallory-Weiss Tear

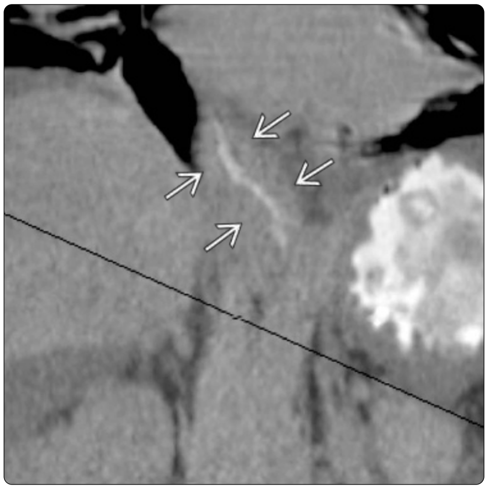


Gastritis-Esophagitis (Axial CT)

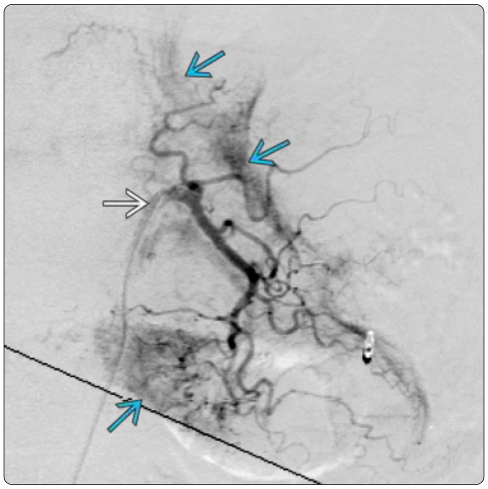


(Left) *A 45-year-old patient with several-day history of hematemesis is shown. Coronal reformatted CT shows circumferential thickening of the distal esophageal mucosa ➡.* **(Right)** *Selective left gastric artery ➡ arteriogram shows patchy areas of hypervascularity in the distal esophagus and stomach → compatible with gastritis-esophagitis.*

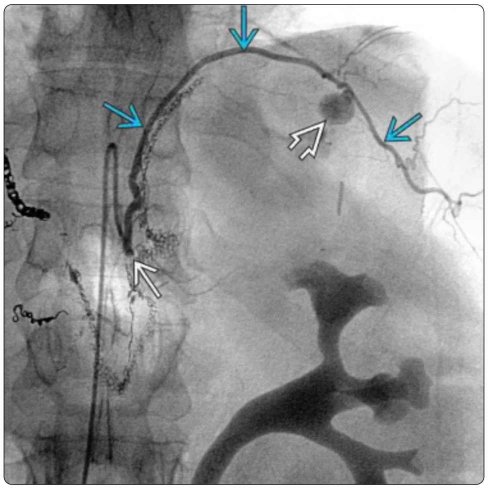
Gastritis-Esophagitis (Coronal CT)



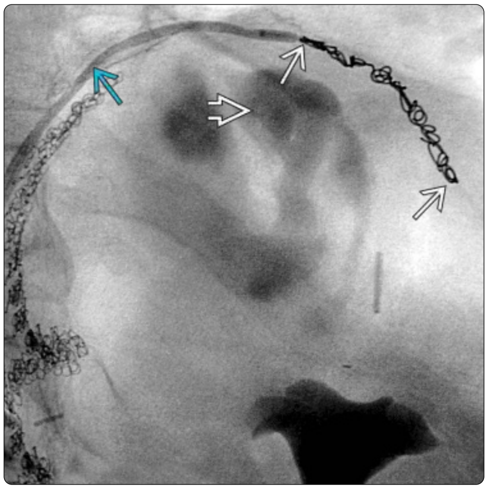
Gastritis-Esophagitis (Left Gastric Arteriogram)



Left Gastric Artery PSA: Pre-Embolization (Left Gastric Arteriogram)

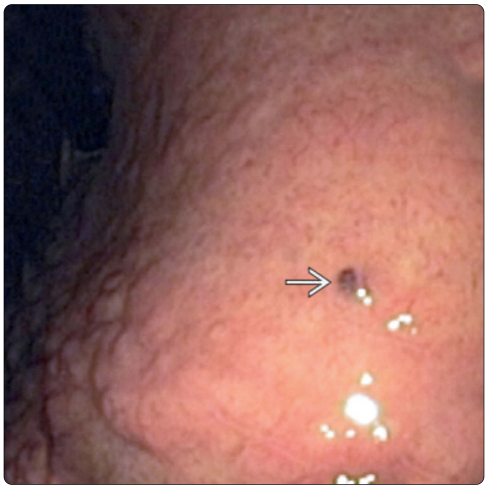


Left Gastric Artery PSA: Post-Embolization (Left Gastric Arteriogram)

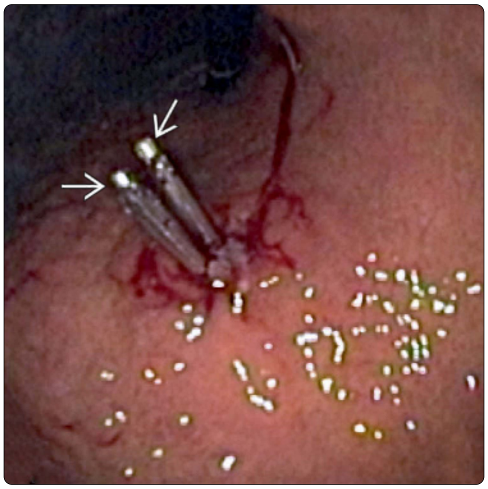


(Left) *A 58-year-old man status post extensive UGI surgery with acute UGI hemorrhage is shown. Selective left gastric arteriogram* ➔ *shows the left gastric artery* ⇨ *draping around the stomach. A pseudoaneurysm (PSA)* ➔ *is noted in the gastric fundus.* **(Right)** *A selective left gastric arteriogram* ⇨ *shows resolution of the PSA after coil embolization both distal and proximal to the PSA neck* ➔*. Coiling distal closes the "back door" and prevents collateral supply to the PSA. Contrast is seen within the stomach* ➔*.*

Gastric Hemorrhage

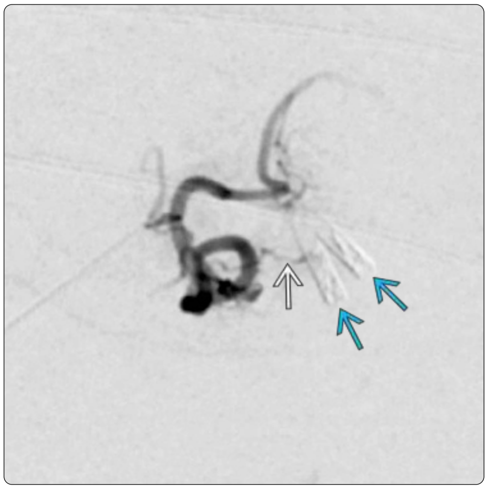


Gastric Hemorrhage

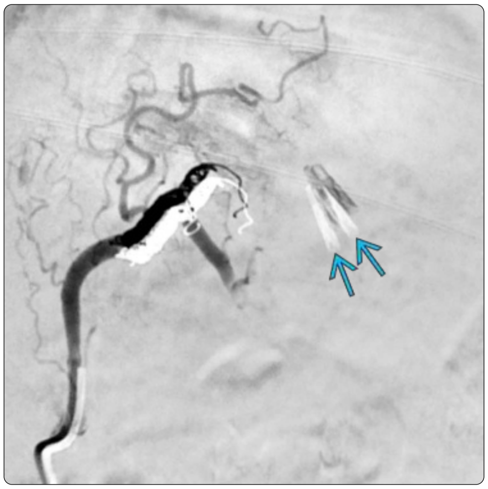


(Left) *A 95-year-old man with chronic, low-grade GI hemorrhage and down-trending hematocrit requiring regular transfusions is shown. Endoscopic view of the stomach reveals a punctate lesion* ➔ *compatible with a submucosal vessel.* **(Right)** *Despite multiple attempts to clip* ➔ *the vessel, the patient continued to hemorrhage and was transferred for an angiogram.*

Gastric Hemorrhage: Active Contrast Extravasation



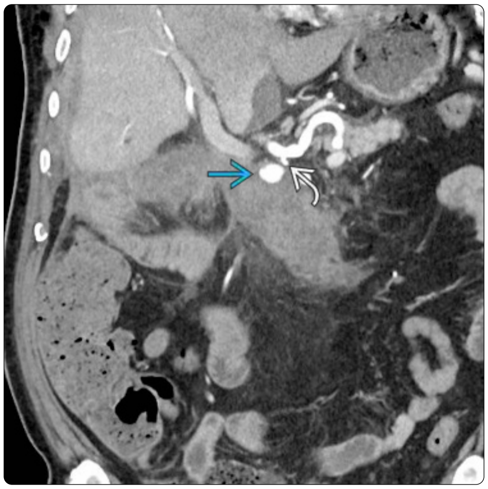
Gastric Hemorrhage: Post-Embolization (Left Gastric Arteriogram)



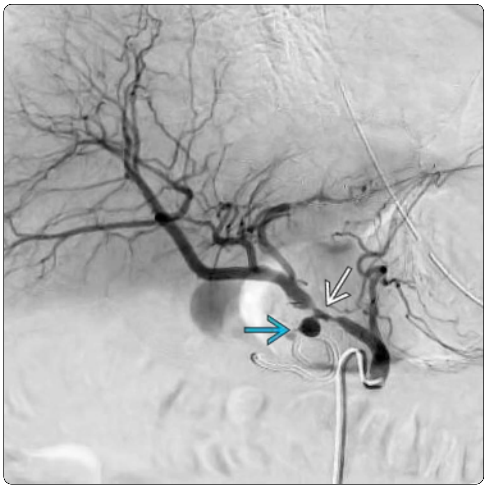
(Left) *A selective left gastric arteriogram shows a small gastric branch* ➔ *with extravasation in the region of the endoscopically placed clips* ⇨*.* **(Right)** *After coil embolization of the left gastric artery, the extravasation in the region of the clips* ⇨ *is no longer visualized.*

(Left) *A 55-year old man status post Whipple surgery for pancreatic adenocarcinoma presenting on postoperative day 2 with upper GI hemorrhage is shown. CT angiogram shows a PSA* → *adjacent to the gastroduodenal artery (GDA) stump* ↪*.* **(Right)** *Selective celiac arteriogram shows the PSA* → *arising from the GDA stump. Focal stenosis of the adjacent hepatic artery* ➡ *is also noted.*

Pseudoaneurysm at GDA Stump (Coronal CECT)

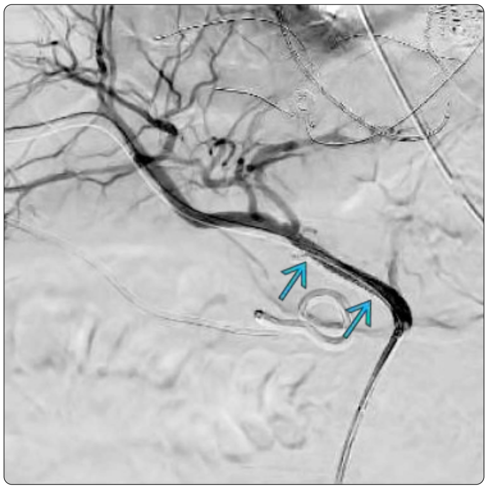


Pseudoaneurysm at GDA Stump (Celiac Arteriogram)

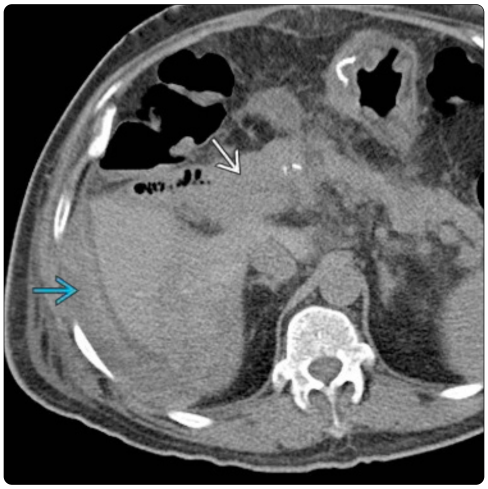


(Left) *Considering the need to preserve hepatic blood flow, the decision was made to use a covered stent. Hepatic arteriogram post covered stent* → *deployment shows resolution of the PSA and the hepatic artery stricture.* **(Right)** *A 65-year-old male patient status post Whipple surgery for pancreatic adenocarcinoma presented with upper GI hemorrhage. CT shows high-density fluid in the pancreatic surgical field* ➡ *and in the perihepatic region* → *compatible with blood products.*

Pseudoaneurysm at GDA Stump (Post Stent Deployment)

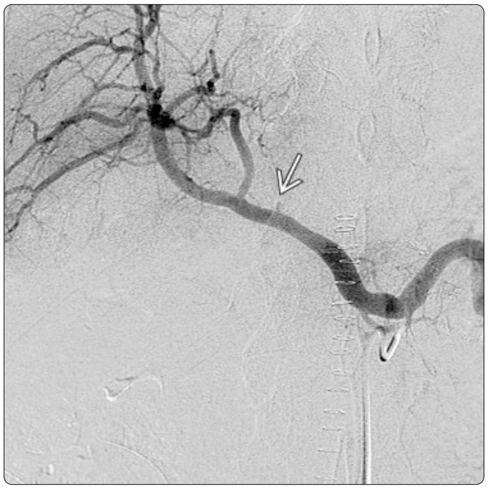


Post-Whipple UGI Hemorrhage (Axial CT)

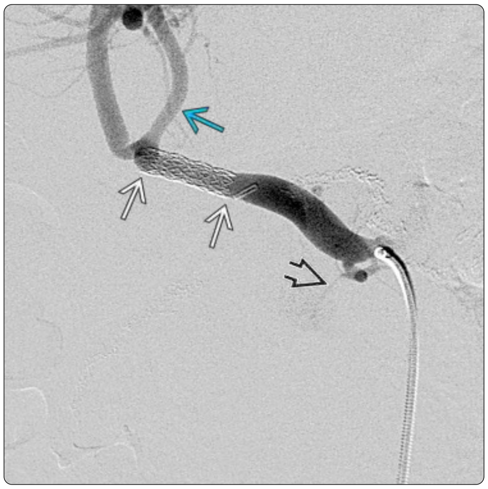


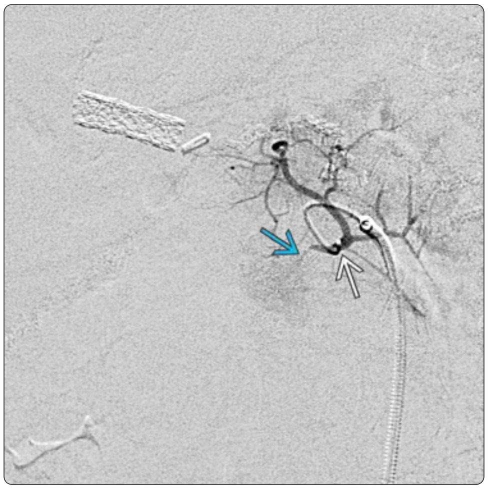
(Left) *Selective celiac arteriogram shows a subtle defect* ➡ *at the clamp location (confirmed by surgery). Contrast extravasation can be subtle on DSA. Power injection, breath-hold images, and multiple views may help increase the sensitivity.* **(Right)** *Selective celiac arteriogram after covered stent* ➡ *deployment shows resolution of the focus of extravasation and patency of the nearby middle hepatic artery* →*. A 2nd area of hemorrhage is identified as a jet of contrast is seen filling a PSA* ⇨*, again a subtle finding.*

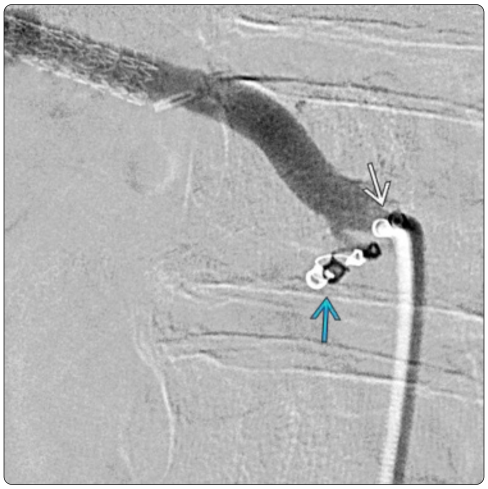
Post-Whipple UGI Hemorrhage (Celiac Arteriogram)



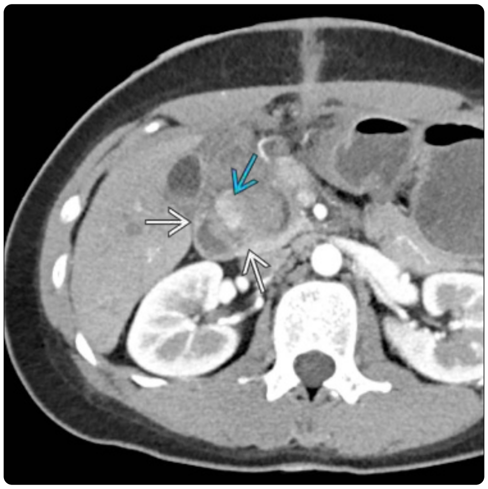
Post-Whipple UGI Hemorrhage (Post Stent Deployment)

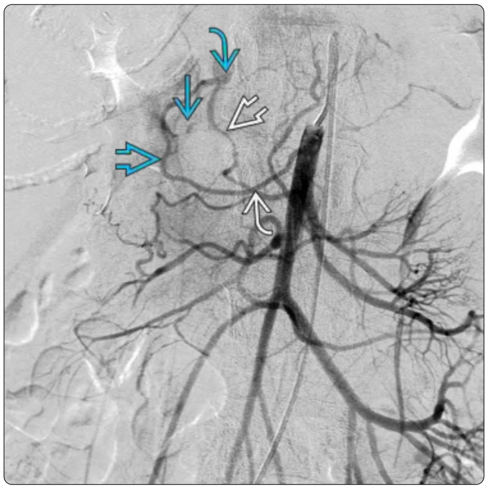



Post-Whipple UGI Hemorrhage (Additional Hemorrhage)

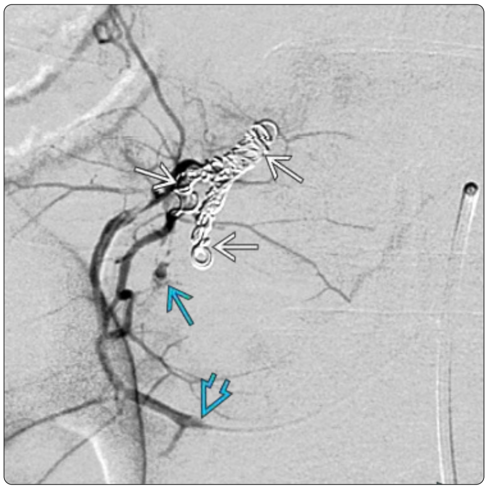

Post-Whipple UGI Hemorrhage (Post Coil Embolization)

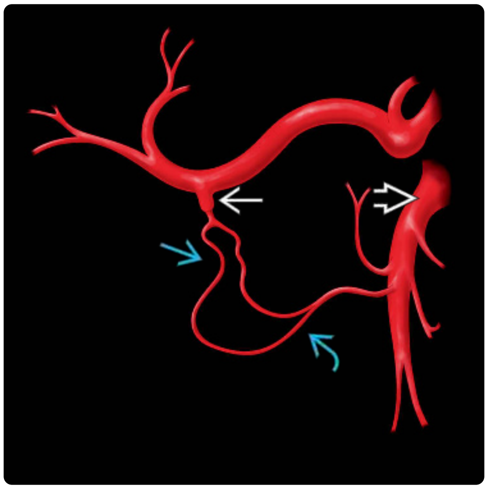
(Left) *Superselective digital subtraction angiogram with the microcatheter* ➡ *in the injured branch better delineates the finding* ⇨*.* **(Right)** *Digital subtraction angiogram via the sheath seated in the celiac artery* ➡ *shows effective coiling of the injured branch* ⇨ *and no further extravasation.*


Pancreaticoduodenal Hemorrhage (Axial CECT)


Pancreaticoduodenal Hemorrhage (Superior Mesenteric Arteriogram)

(Left) *A 56-year old woman status post enucleation for pancreatic head insulinoma, presenting on postoperative day 4 with UGI hemorrhage, is shown. Axial CT shows a large hematoma* ➡ *with focal extravasation* ⇨ *in the surgical bed.* **(Right)** *Superior mesenteric arteriogram reveals a focus of extravasation* ⇨ *in between the anterior* ➡ *and posterior* ⇨ *divisions of the inferior* ➡ *and superior* ⇗ *pancreaticoduodenal arteries.*

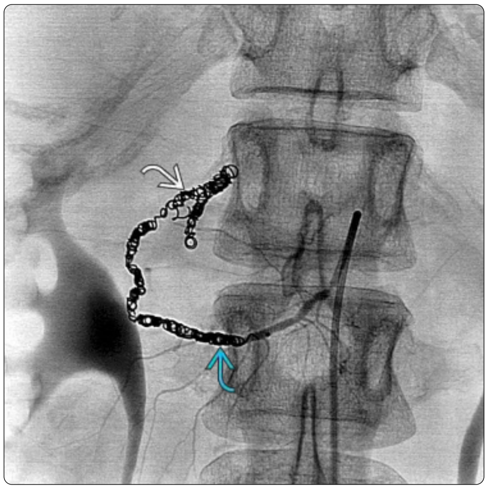

Pancreaticoduodenal Hemorrhage (Post GDA Coil Embolization)


Pancreaticoduodenal Hemorrhage

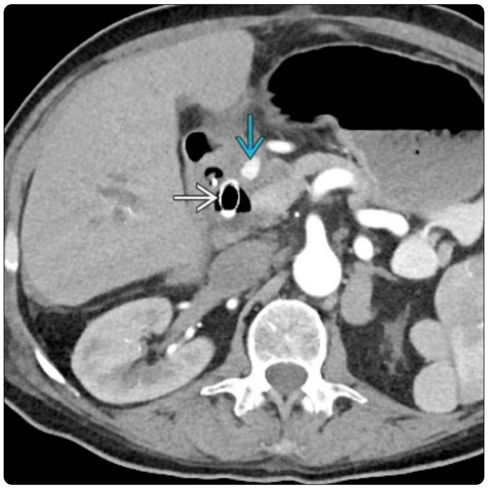
(Left) *After coil embolization of the distal branches of the GDA* ➡ *via the celiac artery, a selective inferior pancreaticoduodenal arteriogram [via the superior mesenteric artery (SMA)]* ⇨ *reveals persistent hemorrhage* ⇨*.* **(Right)** *Hemorrhage in the region of the pancreatic head, duodenum, &/or subhepatic space necessitates interrogation of both the celiac* ➡ *and superior mesenteric* ➡ *arteries, since this region is collateralized by the superior* ⇨ *and inferior* ⇗ *pancreaticoduodenal arteries.*

(Left) *After coil embolization of both the superior* ➔ *and inferior* ⇨ *pancreaticoduodenal arteries, the hemorrhage resolved.* **(Right)** *A 63-yer old woman status post liver transplantation with acute onset abdominal pain, tachycardia, and hematemesis is shown. CT shows a dens "blush"* ⇨ *in the porta hepatis near a previously placed biliary endostent* ➔.

Pancreaticoduodenal Hemorrhage (Post GDA and PDA Coil Embolization)

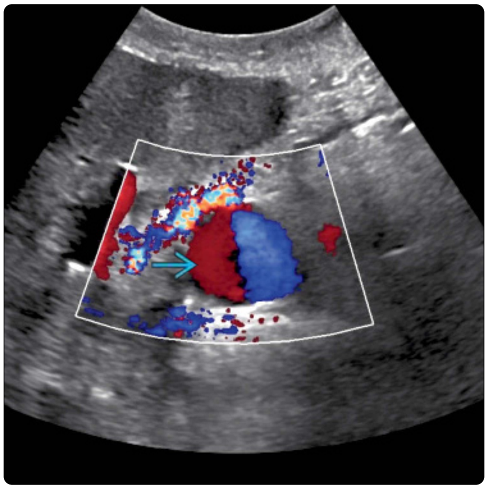


Posttransplant Hepatic Artery PSA (Axial CECT)

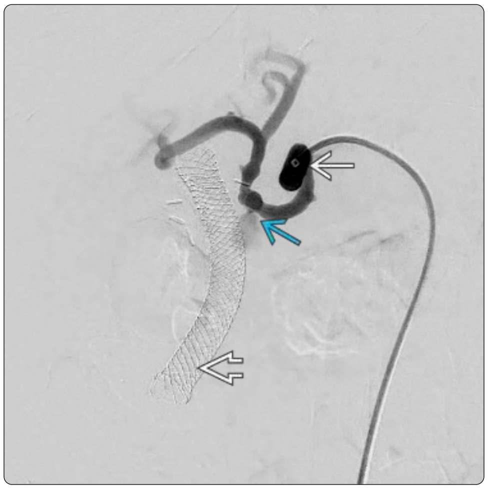


(Left) *Doppler ultrasound examination reveals a large PSA* ⇨ *in the port hepatis. The PSA demonstrates the classic yin-yang sign representing swirling flow.* **(Right)** *Selective celiac arteriogram* ➔ *shows a jet of contrast* ⇨ *into the PSA at the site of the hepatic artery anastomosis. A metallic common bile duct stent is noted* ➔.

Posttransplant Hepatic Artery PSA (Color Doppler Ultrasound)

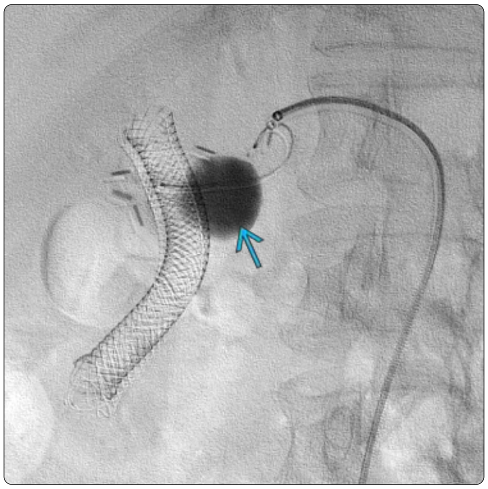


Posttransplant Hepatic Artery PSA (Celiac Arteriogram)

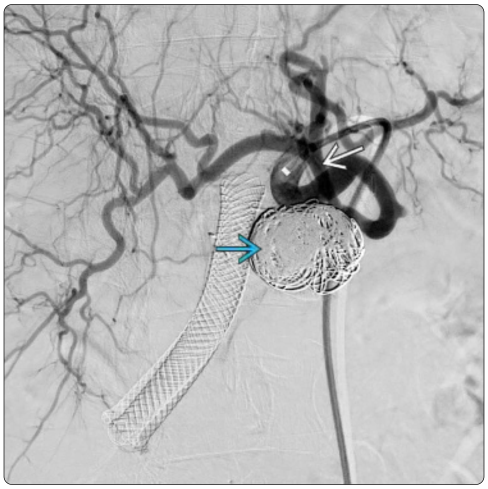


(Left) *Superselective angiogram with a microcatheter in the PSA* ⇨ *fills the narrow-necked defect. Because of the tortuosity of the celiac artery, a covered stent could not be deployed safely. Thankfully, the narrow neck of the PSA makes coil embolization possible.* **(Right)** *Successful coil embolization of the PSA* ⇨ *with microcoils is shown. Good forward flow in the proper hepatic artery* ➔ *is maintained.*

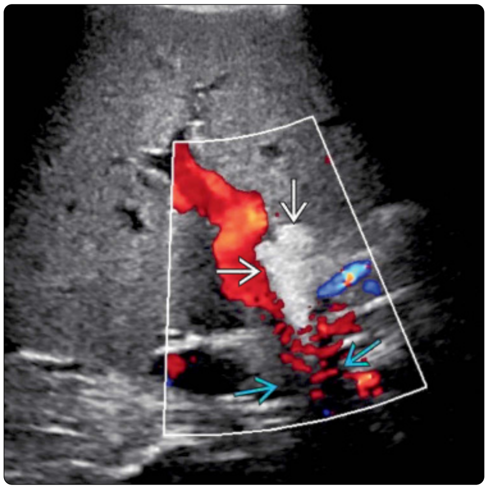
Posttransplant Hepatic Artery PSA (Superselective Arteriogram)



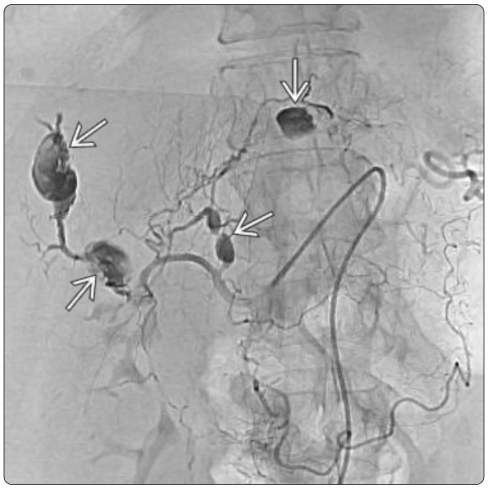
Posttransplant Hepatic Artery PSA (Post Coil Embolization of PSA)



Posttransplant Hepatic Artery PSA (Color Doppler Ultrasound)

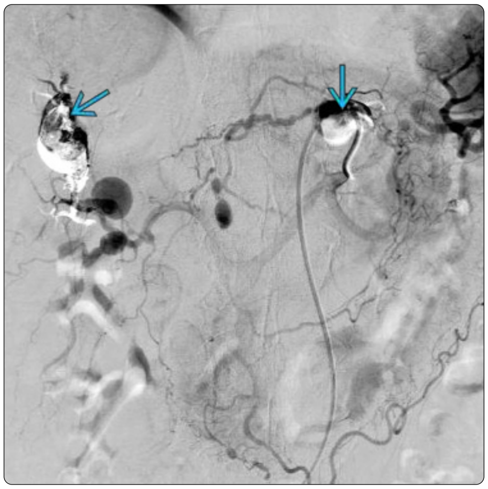


Segmental Arterial Mediolysis (Celiac Arteriogram)

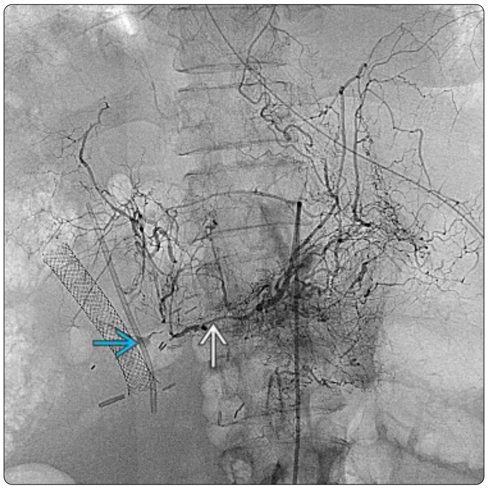


(Left) *Doppler ultrasound following intervention shows complete lack of flow in the previously detected PSA* ➡*. Acoustic shadowing due to the coils is noted* ⇨*.* **(Right)** *An early-phase, selective celiac arteriogram in a 35-year-old woman presenting with massive upper GI hemorrhage, hypotension, and large transfusion requirement shows diffuse vasospasm and multiple PSAs* ➡*. The patient was diagnosed with segmental arterial mediolysis.*

Segmental Arterial Mediolysis: Post Glue Embolization

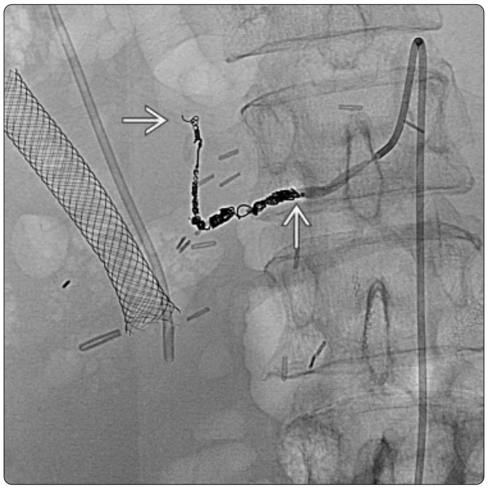


Arteriobiliary Fistula (Celiac Arteriogram)

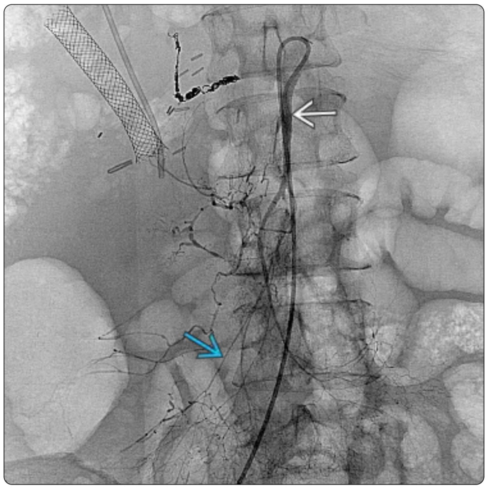


(Left) *The 2 largest PSAs were embolized with glue* ⇨*. Efforts were made to ensure continued perfusion of the nonaffected arteries to minimize the risk of hepatic infarction.* **(Right)** *A 65-year-old woman had massive upper GI hemorrhage after endoscopic common bile duct stent placement. An emergent celiac arteriogram revealed diffuse vasospasm, including the hepatic artery* ➡ *and contrast extravasation from the hepatic artery toward the biliary stent* ⇨*.*

Arteriobiliary Fistula (Post Coil Embolization)



Arteriobiliary Fistula (Superior Mesenteric Arteriogram)



(Left) *Despite the difficulty in accessing the severely spasmed hepatic artery, the vessel was successfully coiled* ➡*.* **(Right)** *SM arteriogram* ➡ *shows no evidence of other hemorrhage. However, the effect of vasopressin is demonstrated as severe diffuse vasospasm* ⇨*. The patient stopped bleeding, and vital signs stabilized. Unfortunately, she expired the day after embolization. Autopsy showed diffuse ischemic bowel necrosis, likely a result of vasopressin-mediated, diffuse vasoconstriction.*

KEY FACTS

TERMINOLOGY

- Hemorrhage from superior mesenteric artery and inferior mesenteric artery territories, distal to ligament of Treitz
- Accounts for 20% of 375,000 patients receiving treatment for arterial GI hemorrhage in USA annually

PREPROCEDURE

- No angiographic contraindication is absolute; risks of intervention should be weighed against risk of not intervening (mortality due to hemorrhage)
- Correct abnormal coagulation profile
- Review of existing imaging, history, exam often reveals cause and site of hemorrhage
    - CT angiography can identify both location and cause of hemorrhage and, in many centers, has replaced nuclear scintigraphy as 1st-line, diagnostic imaging study
- **Embolic agents:** There are variety of embolizations choices, some considered permanent (e.g., coils), others temporary [e.g., Gelfoam (Upjohn, Kalamazoo, MI)]
    - Other times combination of embolization agents may be best option; in many cases, experienced operator's judgment is superior to available literature description

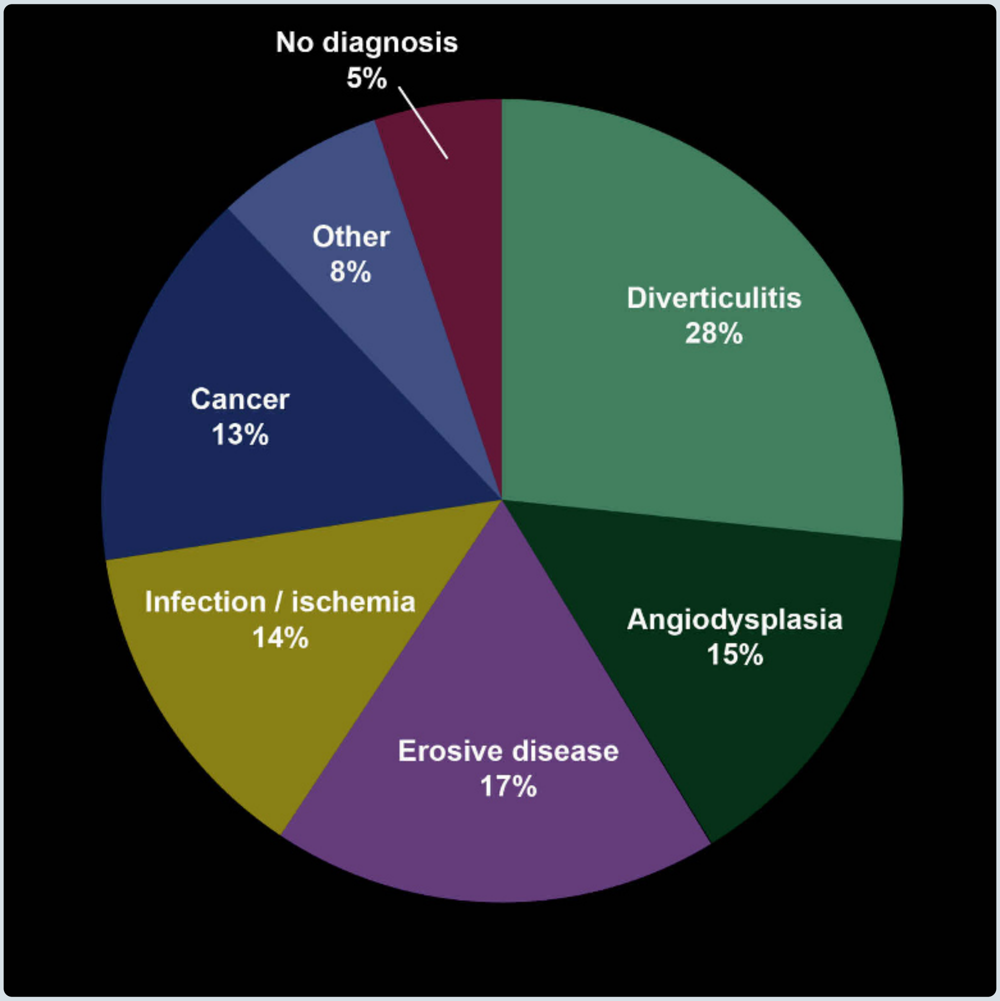
PROCEDURE

- Lower gastrointestinal territory does not have rich collateral supply
    - Risk of ischemia is higher than that in upper gastrointestinal territory
    - Use extra care when embolizing postsurgical bowel

POST PROCEDURE

- 60-80% success rate if hemorrhage is identified on angiogram
- High INR &/or low platelets may allow continued bleeding despite proper embolization

Causes of Lower Gastrointestinal Hemorrhage



In the Western world, the most common cause of lower gastrointestinal (LGI) arterial hemorrhage is diverticulitis. Inflammatory bowel disease, angiodysplasia, and cancer are also important contributors to the incidence of LGI hemorrhage.

TERMINOLOGY

Definitions

- **Lower gastrointestinal (LGI) hemorrhage**
  - Territory supplied by superior mesenteric artery (SMA) and inferior mesenteric artery (IMA)
    - The middle and inferior rectal arteries are supplied by the internal iliac artery
    - The internal iliac artery must be investigated in cases of distal rectal/anal hemorrhage
  - Boundary between upper gastrointestinal (UGI) and LGI is celiac artery-SMA watershed zone
    - Near ligament of Treitz
  - Some hemorrhages supplied by both celiac and SMA (commonly 2nd and 3rd portion of duodenum)
- Epidemiology
  - ~ 375,000 patients receive treatment for arterial GI hemorrhage in USA annually
    - ~ 20% have LGI source
  - Prior to introduction of endoscopic/endovascular treatments, mortality was 25%
  - Since introduction of endoscopic/endovascular treatments, mortality dropped to 5%
- Causes of LGI hemorrhage
  - Most common cause of LGI arterial hemorrhage is diverticulitis (~ 28%)
  - Secondary causes of LGI hemorrhage
    - Erosive disease (~ 17%)
    - Angiodyslasia (~ 15%)
    - Infection/ischemia (~ 14%)
    - Cancer (~ 13%)
    - Other (~ 8%)

PREPROCEDURE

Indications

- Clinical evidence of active LGI arterial hemorrhage
  - Hypotension
  - Tachycardia
  - Transfusion requirement
  - Pressure support
  - Hematochezia (bright red blood per rectum)
- Imaging evidence of active LGI arterial hemorrhage
  - Endoscopic
    - Direct endoscopy limited to colon
      - ☐ In most cases endoscopy is non-diagnostic because the colon is not prepared
    - Capsule endoscopy may locate hemorrhage in small bowel
  - CT angiogram (becoming important 1st-line study)
  - Tagged red-blood cell study
  - Ultrasound (especially in case of PSA (pseudoaneurysm))

Contraindications

- None are absolute; weigh risks of intervention against risk of not intervening
- Potential contraindications include
  - Uncorrectable coagulopathy
    - Packed red blood cells (PRBC) are anticoagulated with citrate phosphate dextrose formulations
    - Massive transfusions (replacing the patient's blood volume in 24 hrs) may increase INR
    - Fresh frozen plasma (FFP) may be required to replenish coagulation factors in patients who receive massive transfusions
  - Allergy to contrast (premedicate)
    - If urgent, consider general anesthesia for airway control
  - Active infection
    - If elective and anticipate hardware implantation (covered stent, coils), may delay intervention for antibiotic treatment
    - Stent, coil bacterial seeding is extremely rare and risk should not delay urgent intervention
  - Prior surgery with altered vascular anatomy
    - Surgical vascular ligation may increase risk of ischemia after embolization
    - LGI territory does not have rich collateral supply; risk of ischemia is higher than that in UGI territory
    - Caution: Ischemia may occur when embolizing after surgical intervention in LGI bowel

Preprocedure Imaging

- **Endoscopy**
  - Useful even if operator unable to stop hemorrhage
    - Identification of location of hemorrhage allows for superselective angiogram
      - ☐ May allow provocative angiogram increasing chance of detecting hemorrhage
    - Sensitivity of LGI endoscopy significantly < that of UGI, since colon rarely prepped for acute endoscopy
  - Capsule endoscopy may be useful to guide angiography in small bowel
    - Cooperation with GI important to delineate exact location of hemorrhage as indicated by capsule endoscopy
- **Computed tomography (CT)**
  - CT angiography is proven tool to identify both location and cause of hemorrhage.
    - In many centers, CT angiography has replaced nuclear scintigraphy as 1st-line, diagnostic imaging study in stable patient
  - IV contrast only; no oral contrast
  - Even noncontrast CT can be helpful by revealing intra- or extraluminal blood (high-density fluid)
- **Nuclear scintigraphy**: May help localize most likely bleeding source/arterial territory
  - High sensitivity and specificity, 90% and 80%, respectively
  - Can be very useful for lower GI hemorrhage
    - Endoscopy has low sensitivity and technical success
    - Small volume hemorrhage can be undetectable by angiography
    - Can be useful in indicating territory of hemorrhage
    - Empiric embolization is not as safe as in upper GI system
  - Do not delay angiography for nuclear scintigraphy if there are clinical signs of active hemorrhage
    - All GI hemorrhages are intermittent
    - Hours-long delay to obtain study may limit sensitivity of angiography

- **Ultrasound**
    - Hemorrhage after surgery or trauma can result in PSA
        - Ultrasound can diagnose PSA as well as confirm resolution of PSA post embolization
    - Routine use of ultrasound as preembolization diagnostic imaging modality is not recommended unless specific need to exclude PSA

Getting Started

- Things to check
    - **Evaluate patient**
        - Assess urgency
        - Assess for adequate venous access
        - Appropriate fluid and blood resuscitation
        - Availability of blood products (PRBC, FFP, platelets)
        - Understand pressor requirement and titration
        - Establish code status (DNR/DNI?)
    - **Evaluate clinical history**
        - May shed light to cause and/or location of hemorrhage
            - History of diverticulitis
            - Vasculitis or use of medications that may cause vasculitis
            - Cirrhosis/portal hypertension should raise suspicion of venous hemorrhage
            - Recent surgery
            - Unresected primary colon cancer
        - Allergies to medications or other agents to be used (sedation, contrast agent, titanium)
        - Assess sedation vs. anesthesia risk (aspiration, difficult airway, markedly obese, short neck, difficult to intubate, previous reaction to sedation, HIV, etc.)
    - **Patient preparation**
        - Consent
            - Discuss potential postembolic bowel ischemia, renal impairment, intermittent nature of GI bleed inhibiting localization/treatment, access complications
            - If unconsentable, obtain consent from next of kin
            - If no next of kin is available, document emergent nature and proceed with angiography ± embolization
            - Inform patients/next of kin that more than one intervention may be needed
        - Laboratory values
            - Evaluate complete blood count (CBC), coagulation profile, and basic metabolic panel (BMP)
            - If elevated creatinine, much of contrast volume can be substituted with CO_2
            - Evaluate trends, not only single values; for example, Hct of 30 is more onerous if previous value was 40 instead of 30
        - Special attention should be paid to coagulation profile
            - Anticoagulated blood does not clot and may render coil embolization ineffective
            - INR < 1.8: If higher, may give fresh frozen plasma; vitamin K takes longer to have effect on INR
            - Platelets > 50k: If lower, may transfuse platelets
            - Values outside these guidelines are not absolute contraindications to intervention
            - Risk of not intervening must be considered in decision-making process
            - Access sheath may be left in place until coagulation profile allows safe removal and should not in itself be reason to deny intervention
            - Many centers have instituted Massive Transfusion Protocols (MTP)
            - MTP automatically replenish coagulation factors with FFP and platelets depleted when large PRBC transfusions are given
    - **Team preparation**
        - If under anesthesia, communicate with anesthesia team intervention plan, risks, anticipated outcomes, and expected postoperative needs
        - Time out: Everyone must know plan
        - Team must be able to perform advanced cardiovascular life support (ACLS)
            - ACLS training saves lives
        - Team must be in effective communication with referring team and unit
        - There must be postembolization (1) treatment, (2) monitoring, and (3) potential reintervention plan
        - Equipment and supply (including resuscitation agents, crash cart)
- Medications
    - **Sedation agents**
        - Fentanyl/midazolam typically used
        - Propofol if one is trained for deep sedation
        - General anesthesia may be necessary in unstable patients
            - General paralysis preferred over spontaneous respiration, to eliminate motion artifact during angiography
    - **Glucagon (1 mg IV)**
        - Slows bowel peristalsis and mitigates misregistration artifact
        - Use with caution if history of diabetes
    - **Provocative agents**
        - Vasodilators
            - Nitroglycerin 100 μg
            - Calcium channel blockers
            - Allow for vasospasm prevention
            - Potentially improve diagnostic accuracy of angiogram by provoking hemorrhage
        - Tissue plasminogen activator (TPA), 2 mg via selective catheter
            - Provoking hemorrhage with TPA can allow embolization in rare instances, if territory of hemorrhage is known (from prior imaging) and catheter access is selective in that territory
            - Heparin can be given instead (less likely to provoke hemorrhage as it is not thrombolytic agent)
    - **Vasopressin, continuous infusion**
        - Rarely used because
            - High incidence of rebleeding, reduces hemorrhage by generalized vasoconstriction
            - Potential systemic side effects (myocardial, bowel ischemia)
            - May require prolonged administration (days)
- Equipment list
    - **Sheaths**

  - Short 5-Fr vascular sheaths for uncomplicated cases
  - Longer, larger vascular sheaths can engage 1st-order target vessel (i.e., celiac artery or SMA) and allow for:
    - Covered stent deployment
    - Stability in complicated cases
    - Rescue interventions in case of complications
- **Catheters**
  - 5-Fr catheters of multiple shapes to allow access in variety of vascular anatomic variations
  - Microcatheters
    - High flow if large volume contrast injection expected
    - High flow if glue or particle use is expected
    - Non-high flow if coil delivery is expected
- **Wires**
  - Regular 0.035" for sheath, catheter access
  - Microwires
    - Large variety increases chances of successful target vessel access
    - Soft microwires allow for distal access in tortuous anatomy but provide poorer catheter trackability
    - Stiff microwires provide better catheter trackability but difficult to negotiate in complex vascular anatomy
- **Embolic agents**
  - Variety of embolizations choices exist
  - Some considered permanent (e.g., coils), while others temporary (e.g., Gelfoam [Upjohn; Kalamazoo, MI])
    - However, coils may occasionally fail to arrest flow (when INR is high); Gelfoam occasionally may result in permanent vessel thrombosis
  - Combination of embolization agents may be best option
  - Experienced operator's judgment is superior to available literature description
  - **Coils:** By far most common embolization agent for GI hemorrhage
    - Introduced through either 5 Fr catheter (0.035", regular coils) or non-high-flow microcatheter (0.018", microcoils)
    - Metallic coils come in variety of sizes, shapes, and designs
    - As small as 1x2 mm straight, to upwards of 20-mm coiled diameter
    - Maybe fibered (promote clotting), expandable gel-coated, or bare
    - Pushable coils: Cannot be retrieved; pushed by wire or hand injected using saline syringe; this method is reserved for end vessel where coil cannot be lost downstream, with good catheter stability
    - Retrievable coils: Can be partially deployed, retrieved, and redeployed; used when there is high risk of nontarget embolization (e.g., arteriovenous fistula embolization, non-end vessel embolization, poor sheath/catheter stability)
    - May use snare (microsnare) to retrieve lost coil in non-target embolized vessel; if lost coil is unlikely to cause complications (i.e. small hepatic artery branch, or small distal pulmonary artery branch), may be best not to attempt retrieval
    - After measuring vessel diameter, oversize arterial coil by 20%, venous coil by 50% or more to ensure stability
    - Caution: High-flow shunting may allow undersized coil to shunt through and embolize distally, e.g., lungs
    - Caution: "Oversized" coil may remain uncoiled, extending proximally out of intended target vessel
  - **Gelfoam slurry:** Theoretically, a temporary agent resorbed at 1-3 weeks
    - Used when hemorrhage is due to temporary condition
    - Rarely indicated for LGI hemorrhage due to small vessel volume
    - Cut Gelfoam in small cubes (~ 1 mm each) and fill 10-cc syringe to 1/2, fill rest with contrast; using 2nd syringe and 3-way stop-cock, form slurry by vigorously pushing mixture between syringes (partially close 3-way stop-cock to make thinner slurry)
    - Stasis is quick; inject very small amount and recheck for embolization
    - Caution: Use only in end-vessels, avoid in cases where macro shunting is present
    - Caution: Consider "dead volume" of delivery catheter to prevent over embolization/Gelfoam reflux into nontarget vessel
  - **Liquid embolic**
    - **"Glue", N-butyl cyanoacrylate TRUFILL (Cordis; Bridgewater, NJ)**
    - Glue is mixed with radiodense lipiodol for opacity
    - Higher lipiodol-to-glue ratios (i.e., 8-1 by volume) polymerize more slowly, allowing more distal, small vessel embolization
    - Lower lipiodol-to-glue ratios (i.e., 1-1 by volume) polymerize very quickly, best suited in high-flow system/small arteriovenous shunting to avoid nontarget embolization
    - Caution: Anything ionic (blood, saline, dirty gloves, etc.) precipitates polymerization clogging catheter/prematurely terminating procedure
    - **Onyx (ev3 neurovascular; Irvine, CA)**
    - Not adherent to vessel wall, occludes by filling luminal space
    - 2 densities: 18 and 34, thinner and thicker respectively
    - Edges polymerize while center remains liquid (lava-like filling of vessels)
    - Solvent is DMSO
    - Rarely indicated for lower GI hemorrhage
    - Caution: Onyx sparks when cauterized (monopolar electrocautery); warn surgeons if surgery is planned
    - Caution: Consider "dead volume" of catheter to prevent over embolization and reflux into nontarget vessel
    - Caution: Prolonged contact of liquid embolic with catheter may result in catheter occlusion
    - Caution: Arteriovenous shunting can allow liquid embolics to bypass target, embolizing lungs or other nontarget vessels
    - Caution: Use preferentially in end vessels; avoid in cases where macro shunting is present

- **Particles**
  - Rarely indicated for GI hemorrhage
  - Relevant particle diameter ranges from 45μm to 900μm
  - Use only in end vessels
  - Particles arrest flow rather quickly; infuse small amount and recheck for stasis
  - Until recently, use of particles in GI system was to be avoided for fear of ischemia
  - Recent studies show risk of LGI ischemia not as significant as previously held
  - Risk of LGI ischemia is higher compared to coil or Gelfoam embolization
  - Use of smaller size particles and embolization of larger areas increases risk of ischemia
  - Caution: More dilute particle mixture takes longer to reach stasis; however, inadvertent nontarget embolization less likely to result in ischemia
  - Caution: Consider "dead volume" of catheter to prevent over embolization and reflux into nontarget vessel
  - Caution: Use preferentially in end vessels; avoid in cases where macro shunting is present
- **Covered stents**
  - Low profile, covered stents allow nonembolic method of addressing hemorrhage
  - Advantageous when patency of injured vessels is desired (e.g., SMA trunk)
  - Long, stable sheath required to deliver stent with accuracy and perform necessary exchanges (balloon, stent, etc.)
  - Oversize stents by 10-20%
  - Deployment may be difficult in tortuous vessels
  - Caution: Do not to cover important side branches; appropriately select stent length
- **Autologous blood clot**
  - Withdraw small amount of patient's blood, allow exposure to partially clot, and inject via catheter
  - Inexpensive and quick
  - Difficult to see during delivery
  - Difficult to judge volume delivered
  - Effect is temporary, definitive treatment preferred for LGI bleed
  - Poor substitute for Gelfoam, which is also inexpensive but longer lasting and can be made opaque
  - Caution: Not advisable for LGI bleed
- **Vasopressin infusion**
  - Place catheter into target artery
  - Initiate vasopressin at 0.2 U/min
  - Repeat DSA at 20-30 min
  - If continued bleeding, increase rate by 0.1 U/min, then repeat DSA at 20-30 min
  - Increase infusion to maximum rate to 1-2 u/min
  - When hemorrhage controlled, secure catheter, reduce dose by 50%, continue infusion for 12-24 hrs
  - Taper vasopressin off over 24-48 hrs
  - Fallen out of favor: High recurrence rates, high complication rates, development of better alternatives
  - Vasopressin given systemically for pressure support: Resulting diffuse vasoconstriction may limit sensitivity of angiogram and limit catheterization
  - Caution: Systemic vasoconstrictive effect may result in organ ischemia, high risk of rehemorrhage

PROCEDURE

Equipment Preparation

- Proper planning is crucial factor that contributes to success of intervention
  - In most cases, review of existing imaging studies, history, signs, and symptoms reveals cause and site of hemorrhage
  - In such cases, procedural steps must be determined priori
    - Plan access and access stability (length and size of sheath)
    - Plan sequence of diagnostic angiograms
    - Have catheters/microcatheters, wires, and embolization agents available
    - Anticipate possible complications and plan mitigating interventions
      - Snare for lost coil?
      - Covered stent for surgical anastomotic rupture?
      - Closure device available?

Procedure Steps

- **Procedure-specific goals**
  - Angiogram of IMA and SMA territories at minimum to localize bleed
  - Halt bleeding with embolization of feeding vessels
- **General**
  - Time out
  - Discuss plan and potential complications with interventional team and all other staff participating
  - Team must be prepared and able to provide ACLS
  - Ensure adequate pressure support and blood product availability
  - General anesthesia can provide extra layer of safety and allow interventionalist to concentrate on procedure, but it is not an absolute requirement
  - Following intervention remove catheter/sheath
  - If abnormal coagulation profile and/or expect repeat intervention, may leave sheath in place
- **Access**
  - Selection of access site
    - Most commonly right common femoral artery
    - Radial artery access allows for cephalad access, but longer catheters/microcatheters are necessary
  - Sterile preparation of access site
  - Ultrasound access may be useful
    - if vessels are vaso-constricted due to volume depletion
    - to avoid multiple punctures if abnormal coagulation profile
- **Diagnostic angiography**
  - Directly engage artery suspected of hemorrhage
    - Typically reverse-curve catheter (Simmons I, SOS), rarely Cobra catheter

    - Evaluate SMA and IMA
    - Evaluate IMA 1st if bleed suspected from IMA territory
    - Contrast filling urinary bladder throughout procedure may obscure visualization of IMA territory
    - Utilize microcatheter for superselective engagement of suspected branches
      - Right colic, middle colic, ileocolic, jejunal branches, left colic
      - High-flow microcatheter will improve diagnosis, but non-high-flow required when delivering certain coils
  - Deliver 1 mg IV glucagon to halt peristalsis/improve DSA imaging
  - Ask patient to hold breath or suspend respiration if patient paralyzed and ventilated
  - If hemorrhage not seen, repeat in oblique views
  - If hemorrhage still not seen and strongly suspect hemorrhage from this artery, wait 10-15 minutes and repeat (hemorrhage is intermittent)
  - If hemorrhage still not seen and strongly suspect hemorrhage is from this artery, consider provocative angiogram
  - Power injection preferable to hand injections to generate adequate contrast density and filling of small/spasmed distal arteries
  - Select high rate of frame (4-6 per second) to optimize visualization
  - Abdominal aortogram should be avoided.
    - It is rarely useful and increases contrast volume
    - Perform only if there is a specific indication (i.e. suspicion for aortic-to-bowel fistula, or variant vascular anatomy makes vessel selection difficult)
- **Intervention**
  - Once location of hemorrhage is identified, formulate intervention plan
    - Sheath length, type, and shape; catheter length, type, and shape; need for microcatheter/microwire, embolization method
      - Consider 5 French reverse-curve catheter in SMA/IMA origin (e.g., Simmons I)
      - Consider non-high-flow microcatheter: Renegade 0.18 (Boston Scientific, Marlborough, MA) or Progreat 2.4 (Terumo, Somerset, NJ)
      - Consider GT Glidewire 45 degree or double curve (Terumo, Somerset, NJ), Transend or Fathom (Boston Scientific, Marlborough, MA)
    - Chose embolic agent, covered stent or vasoconstrictor (typically coils)
    - Anticipate possible complications and plan how to avoid or address them
- **Termination**
  - When embolization is complete, perform hand-injected DSA
  - Do not power inject as this may cause coils or Gelfoam to dislodge
  - If there is still flow, deploy more embolics if there is room to do so
    - If no room to safely deploy more coils, small amount of Gelfoam may be useful
  - If there is still flow, wait 2-5 minutes and repeat hand injection
    - Slowed flow may result in thrombosis
  - Caution: It is last coil that causes problems; if there is adequate stasis, resist temptation to use "just one more" coil
  - Pack coils as tightly as possible. A solid "wall" of densely packed coils is much more effective than sparsely packed coils

Alternative Procedures/Therapies

- Radiologic
  - If variceal hemorrhage due to portal hypertension (hemorrhoidal, peri-stomal)
    - Transjugular intrahepatic portosystemic shunt
    - Direct percutaneous peristomal variceal embolization
    - Balloon-occluded, retrograde transvenous obliteration of varices (BRTO)
  - If pseudoanurysm (PSA) is accessible, percutaneous thrombin injection may be effective (i.e. intra-parenchymal hepatic artery branch PSA
- Surgical
  - Surgical exploratory laparotomy ± anatomic resection of bleeding source
    - May require extensive resection, with significant morbidity and mortality, especially in acute setting
      - Surgical treatment for colonic bleed requires hemicolectomy (or even total colectomy) and possible colostomy
      - Surgical treatment for small bowel bleed requires significant portion of small bowel to be removed and anastomosis
  - Angiographic interventions must be exhausted before opting for surgery
- Other
  - Endoscopic management
    - Epinephrine injection/cautery/hemoclip
    - May be repeated ad lib
    - Even if unsuccessful, endoscopy can guide empirical embolization; hemoclips are visible during angiography and mark bleed location, but may dislodge in couple of days
  - Medical management
    - Fluid resuscitation and pressure support
    - Administration of blood products
      - Massive transfusion protocol balances relative need of blood products (RBC, platelets, FFP)
    - Correction of coagulation profile
    - Systemic vasopressin may mitigate hemorrhage by diffuse vasoconstriction

POST PROCEDURE

Things To Do

- Assign proper bed location, usually monitored bed
- Discuss procedure and expected outcome with floor team
- Discuss findings/plan with patient/patient's family
- Have plan for possible reintervention
- Sign-out plan to on-call interventional radiology team
- Monitor access site, as many such patients are coagulopathic

Things to Avoid

- Do not fail to correct abnormal coagulation profile, high INR/low platelets may result in rebleeding despite proper embolization
- Do not assume hematochezia or melena within hours of successful embolization = rebleed
  - Best to judge efficacy by response to transfusion post-embolization
- Do not fail to consider unusual sources of GI hemorrhage
  - Biliary hemorrhage
  - Hemorrhage due to ischemia (i.e., segmental arterial mediolysis)

OUTCOMES

Problems

- Factors that limit sensitivity of angiography
  - Intermittent nature of LGI bleed
    - Perform multiple AP, oblique views
    - Wait few minutes and repeat angiogram
    - Consider provocative angiogram
  - Vasoconstriction related to systemic pressure support (especially with vasopressin)
  - Poor digital subtraction of angiogram
    - Consider reviewing images in native view (without subtraction)
    - Peristalsis, give IV glucagon
    - Patient respiration, consider breath hold with general anesthesia
    - Patient motion, consider deeper sedation or general anesthesia
- Factors that limit efficacy of embolization
  - Unrecognized collateral blood supply
    - Less likely in LGI system
  - Incomplete embolization
  - Persistent coagulopathy
  - Vasodilatation after embolization may allow reperfusion of bleeding source

Complications

- Most feared complication(s)
  - Nontarget embolization
    - Can occur with any type of embolization agent
    - Most "lost" coils can be retrieved but not other embolization agents
    - Exclude AV shunting before embolization
  - Bowel ischemia/infarction
    - Risk is higher in LGI system, which does not enjoy rich collateral supply
      - ☐ Higher with particles, lower with coils
      - ☐ Be cognizant of previous surgery as vascular anatomy may be altered/diminished
- Immediate/periprocedural complication(s)
  - Access site complications
    - Bleeding/hematoma (could be retroperitoneal if high stick)
    - Arteriovenous fistula/pseudoaneurysm
  - Vasopressin infusion
    - Arrhythmias (bradycardia)
    - Antidiuretic hormone side effects (water retention, hyponatremia)
    - Coronary artery vasoconstriction, cardiac &/or systemic ischemia
- Delayed complication(s)
  - Contrast-induced nephropathy
    - Patients often have ≥ 1 recent CECT during current admission
    - Angiography and embolization can often deliver 100 to > 250 cc contrast
    - Intermittent LGI bleed may necessitate multiple angiograms to localize/treat
    - Patients are often hypovolemic from blood loss

Expected Outcome

- If hemorrhage is identified on angiogram, success rate is 60-80%, depending on etiology
  - Patients may have hematochezia or melena for a few hours after procedure without continued or repeat bleed
  - Monitor for signs of rebleed
    - Hct response to transfusion
    - Hct stability AFTER embolization (do not compare pre- and postembolization Hct)
    - Clinical signs of hemorrhage
- Clinical success (termination of bleeding)
  - Initial success may overestimate overall benefit
    - Bleeding reported to recur in 0-52% of patients

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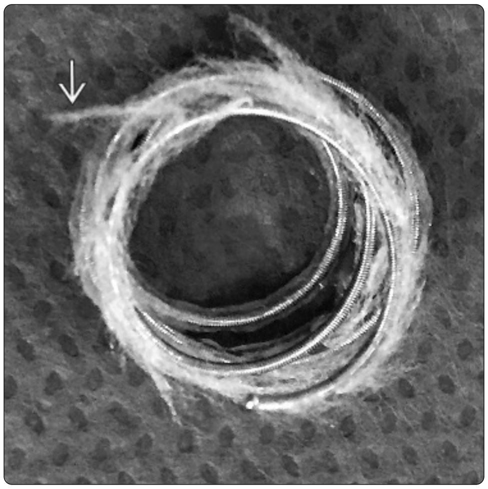
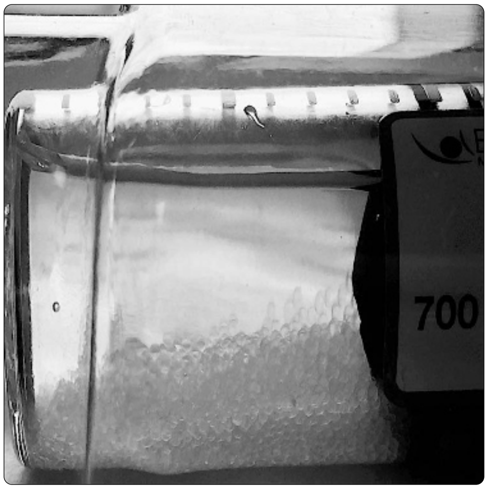
Embolic Agents: Coils

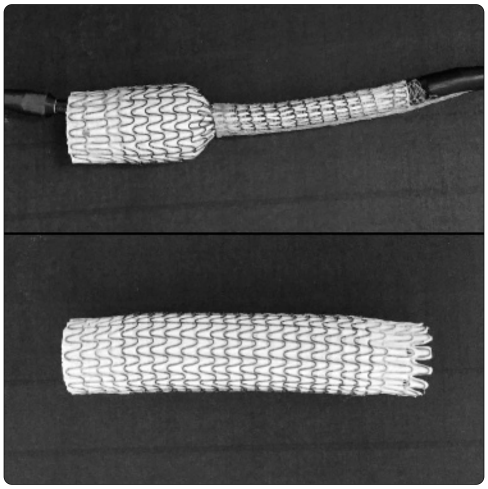


Embolic Agents: Particles in Suspension

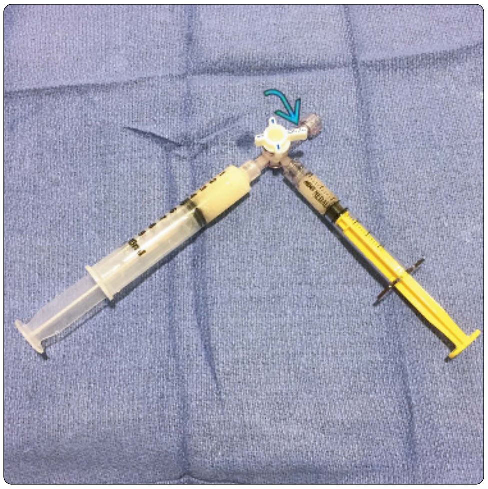


(Left) *The most frequently used LGI hemorrhage embolic device. Coil characteristics include: 0.035 vs. 0.018 catheter, fibered* ➔ *vs. nonfibered, and detachable vs. pushable. Appropriate shape, length, and coiled diameter of a coil is operator and target morphology dependent.* **(Right)** *Embolization particles come in a wide range of sizes (< 45 micron to 900 micron). Due to fears of bowel ischemia (possibly exaggerated), particles are used only in end vessels, and only if other embolization methods are deemed unlikely to succeed.*

Embolic Agents: Covered Stents



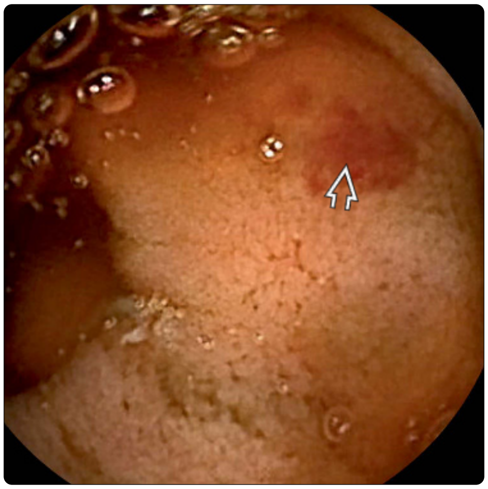
Embolic Agents: Gelfoam Slurry



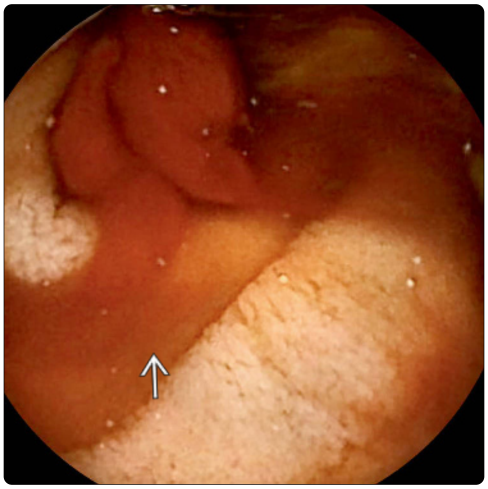
(Left) *Covered, low-profile (self- or balloon-expandable) stents allow for effective treatment of certain types of hemorrhages, while preserving flow in the injured vessel. A partially (upper) and fully (lower) self-expanded covered stent is shown.* **(Right)** *Gelfoam preparation: Cut in small (< 1 mm) cubes and mixed with contrast in a syringe. Slurry is pushed back-and-forth into a 2nd syringe via 3-way stopcock* ↪*, which is narrowed until desired consistency is achieved.*

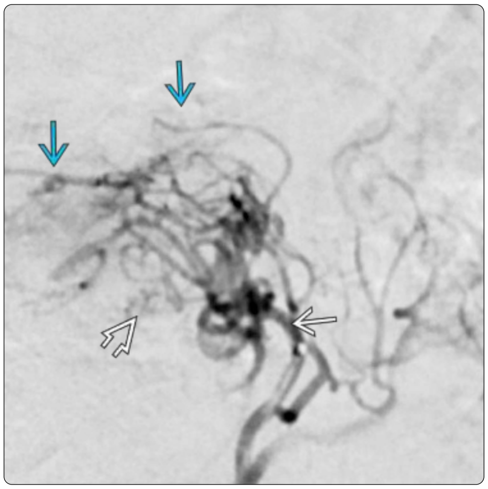
Embolic Agents: Gelfoam Slurry

Duodenal Hemorrhage (Endoscopic View)

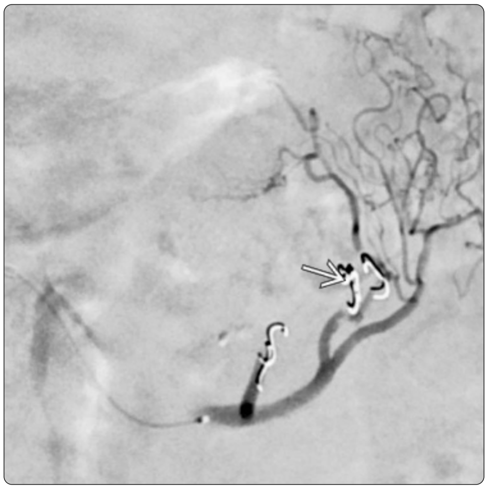


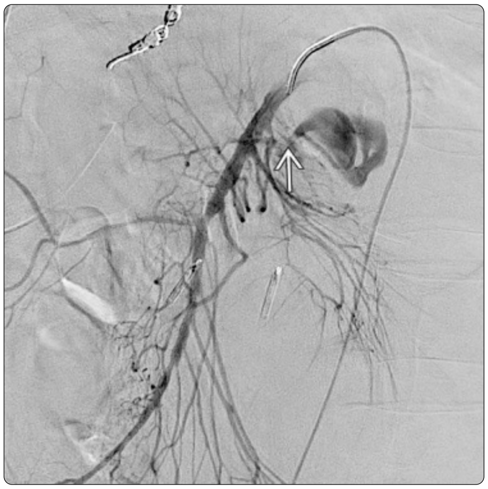
(Left) *Gelfoam slurry* ⇨ *embolization is a quick and inexpensive method of embolization. It however requires experience to avoid over or under embolization. It is considered a temporary embolization agent as it is resorbed over time; therefore, it should used where the vascular injury is likely to heal before recanalization (1-3 weeks).* **(Right)** *Endoscopic attempts failed to treat a punctate region of recent hemorrhage* ➔ *in this elderly man with chronic low-flow hemorrhage requiring regular transfusions to maintain Hct.*


Duodenal Hemorrhage (Endoscopic View)

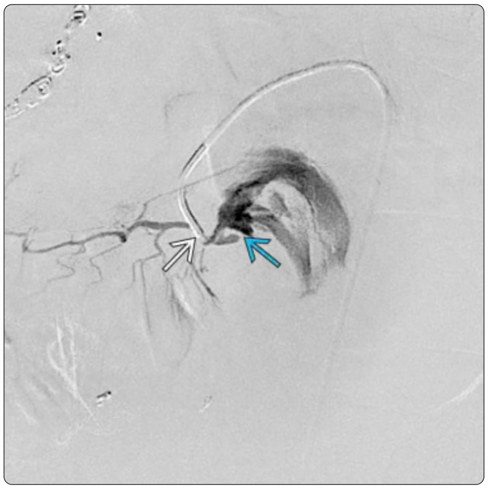

Duodenal Hemorrhage (Diagnostic Angiogram)

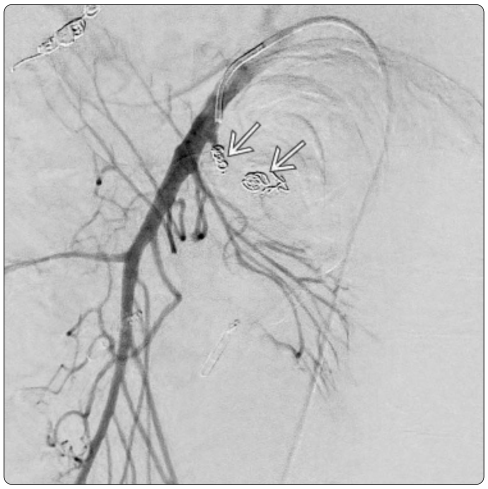
(Left) *Endoscopic view of the distal duodenum in the same patient shows layering blood* ➡ *after attempts to treat endoscopically.* **(Right)** *A superselective angiogram with the microcatheter tip* ➡ *in a small branch off the superior mesenteric artery (SMA) shows a tuft of abnormal vessels* ➡ *under the surface of the distal duodenum* ⇨.


Duodenal Hemorrhage (Post Coil Placement)


Distal Duodenal Hemorrhage (Superior Mesenteric Angiogram)

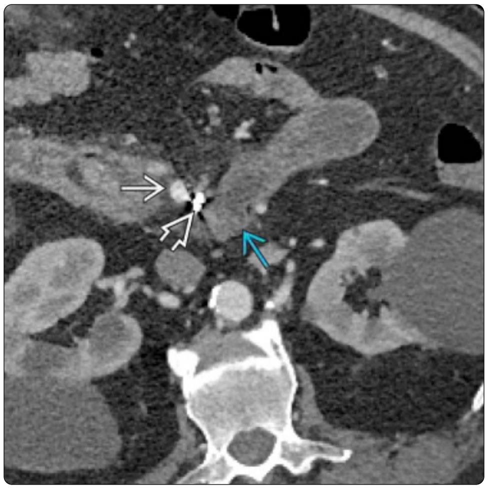
(Left) *A selective arteriogram after coil embolization* ➡ *of 3 tiny branches shows devascularization of the abnormal area of vascularity in the distal duodenum. Bleeding stopped following embolization.* **(Right)** *Superior mesenteric arteriography in an unstable elderly woman post-Whipple, receiving large volume transfusions and pressure support, shows brisk bleeding into the duodenum* ➡ *from a proximal SMA branch.*


Distal Duodenal Hemorrhage (Superselective Angiogram)

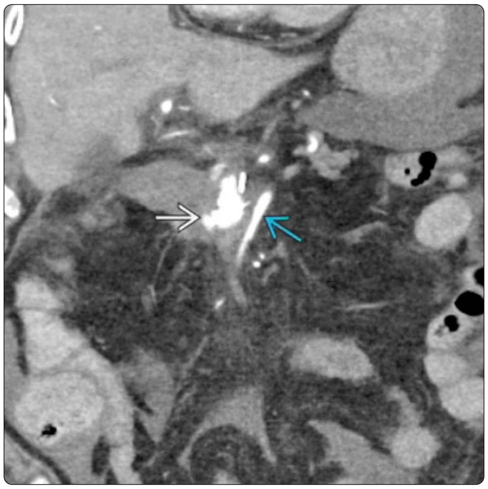

Distal Duodenal Hemorrhage (Post Coil Placement)

(Left) *A superselective arteriogram with the catheter selecting the defect* ➡*, shows the duodenal hemorrhage to better advantage* ⇨*. The distance between the defect and the duodenum is very short and catheter stability is labile. The major side branches precluded the use of a covered stent.* **(Right)** *A selective superior mesenteric arteriogram after coil embolization* ➡ *of the SMA-duodenal communication shows resolution of the hemorrhage.*

Distal Duodenal Hemorrhage (Postembolization CT)

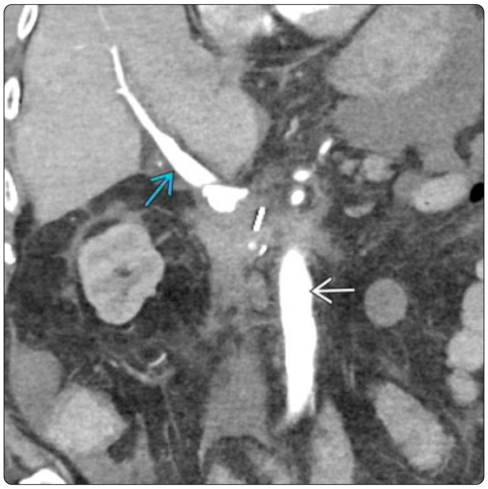


Arterio-portal Fistula (Coronal CECT)

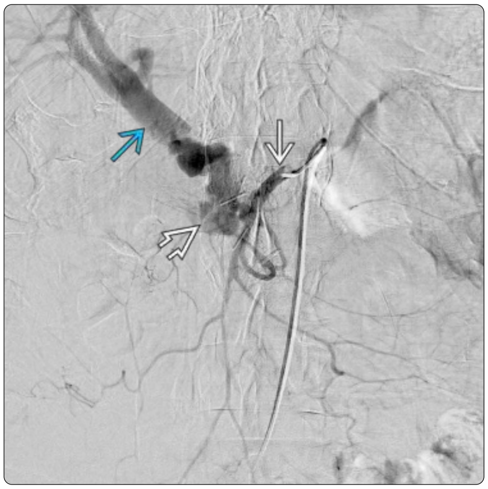


(Left) *A postembolization CT shows the SMA ➡ in close proximity to the distal duodenum ➔. The coils are visualized between the 2 structures ⇨. The patient recovered without further hemorrhage.* **(Right)** *A 55-year-old man post-Whipple procedure presented on postoperative day 3 with a massive upper GI hemorrhage. Coronal CT angiography shows an area of extravasation ➡ to the right of the proximal SMA ➔.*

Arterioportal Fistula (Coronal CECT)

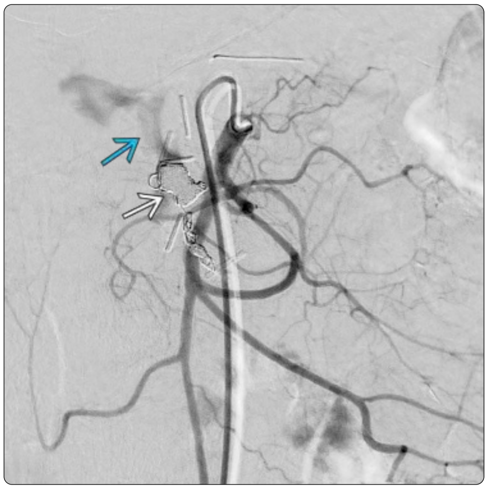


Arterioportal Fistula (SMA Angiography)

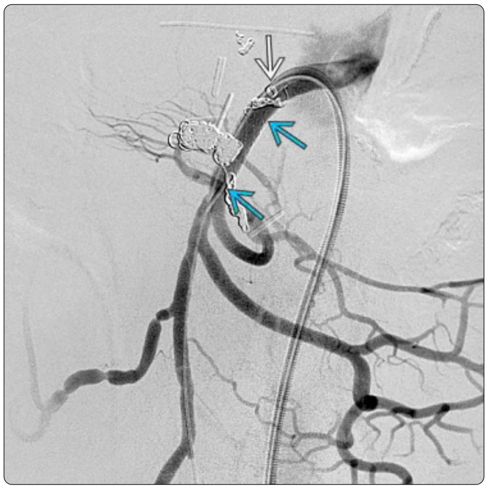


(Left) *In addition to the extravasation, the CT angiograph showed direct communication between the superior mesenteric artery ➡ and portal vein ➔, evidenced by early filling of the latter.* **(Right)** *A selective superior mesenteric arteriogram via a Simmons I catheter ➡ shows the extravasation ⇨ and early filling of the portal vein ➔.*

Arterioportal Fistula (Post Coil Embolization)



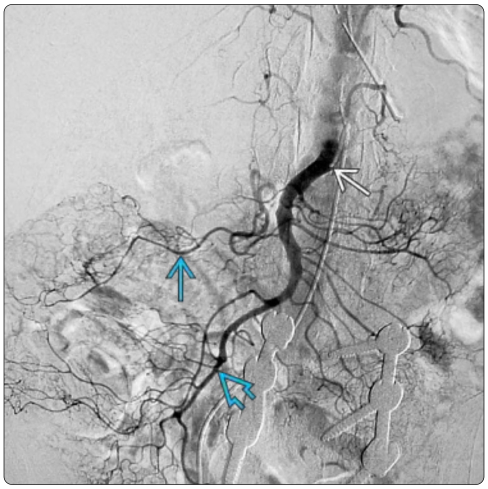
Arterioportal Fistula (Post Stent Placement)



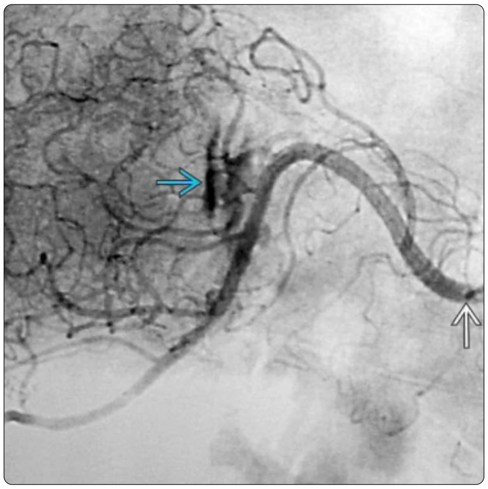
(Left) *A selective superior mesenteric angiogram after coil embolization of the defect ➡ shows decreased but persistent contrast extravasation ➔.* **(Right)** *After exchanging for a long sheath ➡, the area of the defect was excluded by a covered stent ➔. No further extravasation was noted and the patient recovered.*

(Left) *85 yo man with 1-week history of GLI hemorrhage required a total of 60 uPRBC. Endoscopy failed to reveal a source. Nuclear scintigraphy suggested a right colic source. Surgery declined intervention. Selective superior mesenteric arteriogram via Simmons I catheter* ➡ *is unremarkable. The right colic* ⇨ *and ileocolic* ⇨ *branches are noted.* **(Right)** *Due to a lack of alternatives, provocative angiography was performed with 2 mg TPA infused via microcatheter* ➡ *in the right colic artery. A superselective angiogram shows the hemorrhage* ⇨*.*

Provocative Angiography (Superior Mesenteric Angiogram)

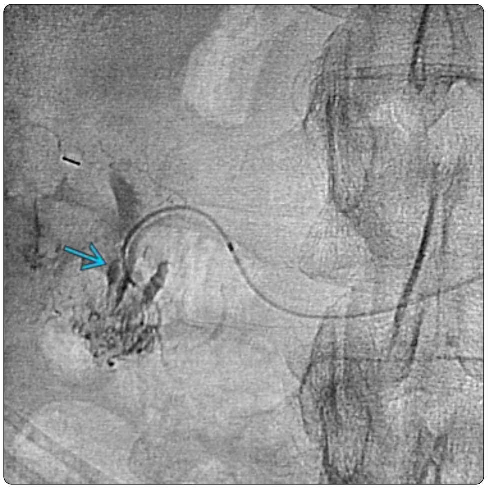


Provocative Angiography (TPA infusion)

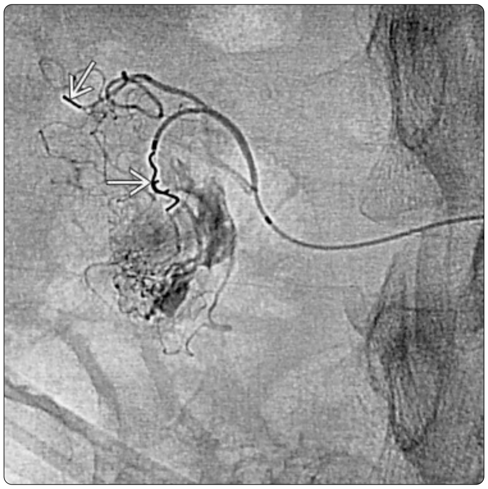


(Left) *After multiple superselective angiograms of branches of the right colic artery, the offending branch was eventually identified, as indicated by extravasation* ⇨*.* **(Right)** *A superselective angiogram of a branch of the right colic artery after coil embolization* ➡ *shows no further hemorrhage.*

Provocative Angiography (Superselective Localization of Bleeding End Artery)

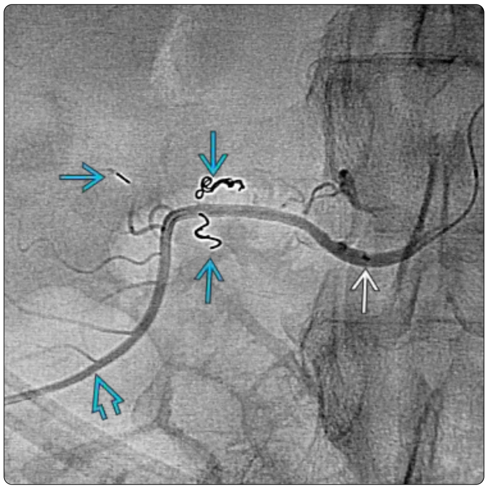


Provocative Angiography (Coil Embolization)

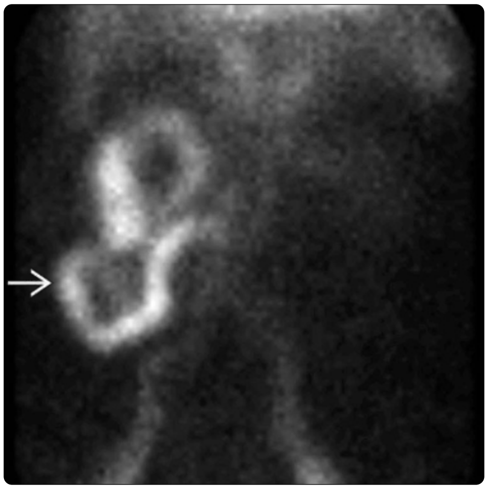


(Left) *A selective completion angiogram of the right colic artery via a microcatheter* ➡ *after coil embolization* ⇨ *of 3 tiny side branches shows no further hemorrhage and good antegrade flow* ⇨*.* **(Right)** *Nuclear scintigraphy in an elderly woman with a 3-day history of melena and downward drifting Hct (despite transfusions) shows serpiginous activity* ➡ *in the right abdomen likely corresponding to distal ileal hemorrhage.*

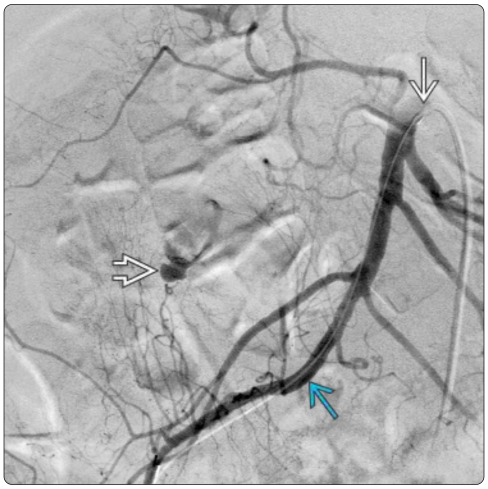
Provocative Angiography (Postembolic Arteriogram)



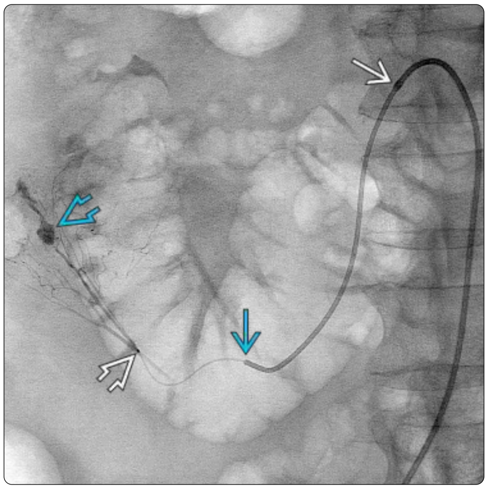
Ileocolic Hemorrhage (Nuclear Scintigraphy)



Ileocolic Hemorrhage (Superior Mesenteric Arteriogram)

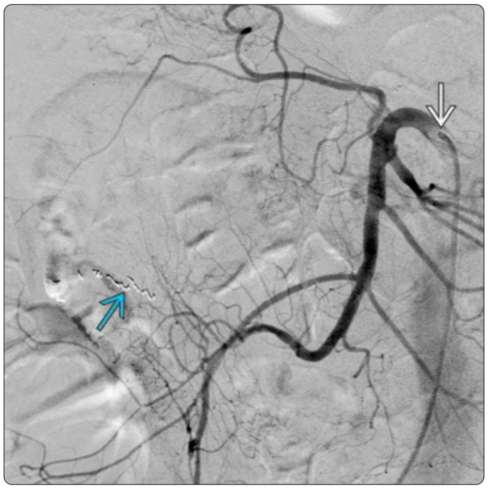


Ileocolic Hemorrhage (Superselective Arteriogram)

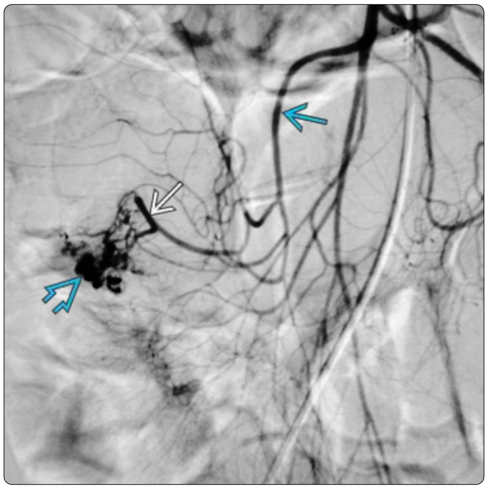


(Left) *A selective superior mesenteric arteriogram via a sheath ➡ shows contrast extravasation ➡ from a branch of the ileocolic artery ⇨.* **(Right)** *A super-selective angiogram of the superior mesenteric artery was obtained using a triaxial system. Note the sheath ➡, 5-Fr glide catheter ⇨, and microcatheter ➡ provide extra stability. Contrast extravasation is present ⇨ in the ascending colon.*

Ileocolic Hemorrhage (Postembolic Arteriogram)

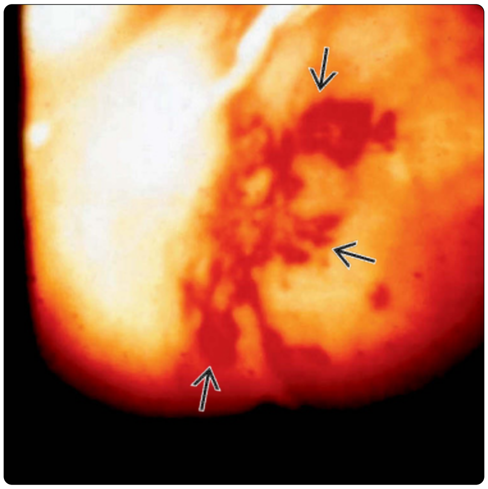


Angiodysplasia of Cecum (Superior Mesenteric Arteriogram)

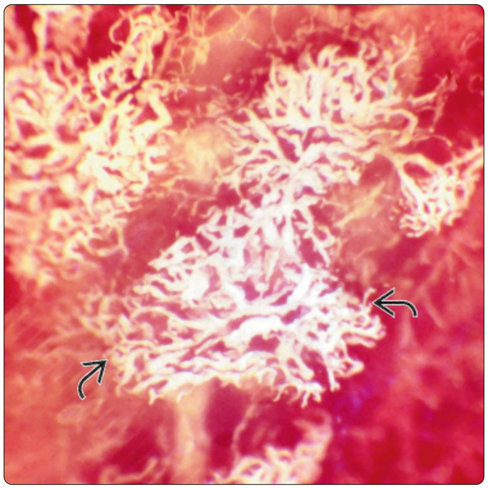


(Left) *Superior mesenteric arteriogram via a sheath ➡ shows resolution of the hemorrhage after microcoil ⇨ embolization.* **(Right)** *A 76-year-old man presented with lower GI hemorrhage. Endoscopy was negative due to a large amount of blood in the unprepared colon. Selective superior mesenteric angiography shows a sausage-like vessel ➡ off of the ileocolic artery ⇨, with hemorrhage in the cecum ⇨ indicative of angiodysplasia.*

Angiodysplasia of Cecum (Colonoscopic Appearance)



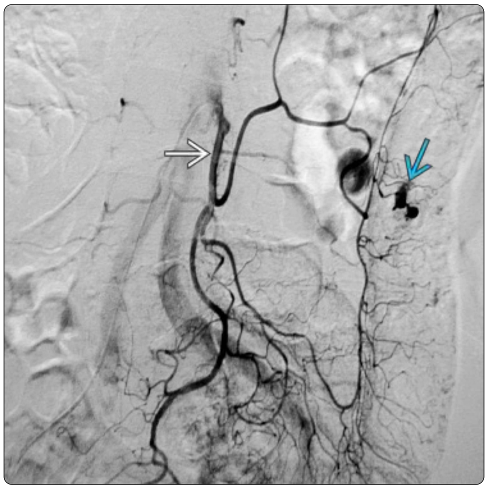
Angiodysplasia of Cecum (Histologic Injected Specimen)



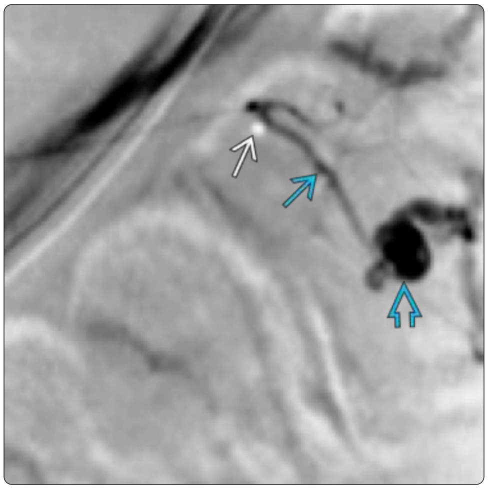
(Left) *Angiodysplasia is much more frequently diagnosed by colonoscopy than by angiography. The endoscopic appearance is one of a discrete, small area of vascular ectasia with scalloped or frond-like edges ⇨ and a visible draining vein. Lesions can be flat or raised and can be hidden in mucosal folds.* **(Right)** *Specimen obtained after injection of the angiodysplastic lesion and fixation in formalin shows the frond-like appearance ↪ of these vascular lesions.*

(Left) *A 69-year-old woman with history of diverticulosis presented with lower GI hemorrhage. A selective inferior mesenteric angiogram* ➡ *shows focal extravasation* ⇨ *in the mid descending colon.* **(Right)** *Magnified, superselective angiography via a microcatheter* ➡ *in the vasa recta* ⇨ *shows the hemorrhage* ⇨ *to better advantage.*

Diverticulitis (Inferior Mesenteric Arteriogram)

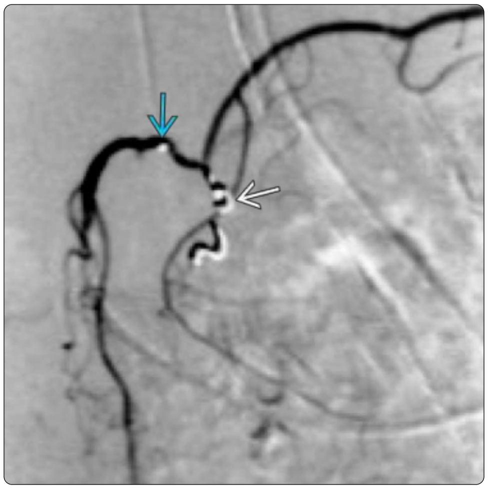


Diverticulitis (Superselective Arteriogram)

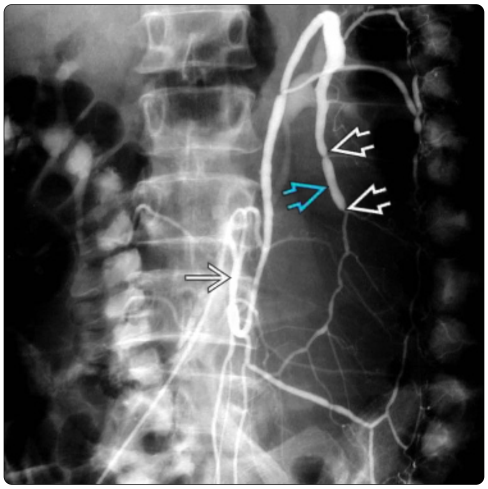


(Left) *A magnified view of angiogram was obtained post microcoil embolization* ➡ *via a superselective microcatheter* ⇨*. The vasa recta is adequately embolized with no further hemorrhage.* **(Right)** *Selective inferior mesenteric angiogram of a 55 year-old man with a few-day history of abdominal pain and lower GI hemorrhage* ➡ *shows diffuse tandem stenoses* ➡ *and dilatations* ⇨ *compatible with segmental arterial mediolysis (SAM). SAM-associated hemorrhage is usually due to ischemia, and embolization may not be indicated.*

Diverticulitis (Postembolization Arteriogram)

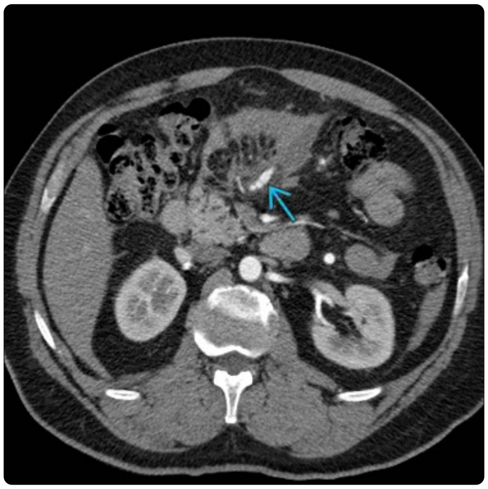


Segmental Arterial Mediolysis (Inferior Mesenteric Hemorrhage)

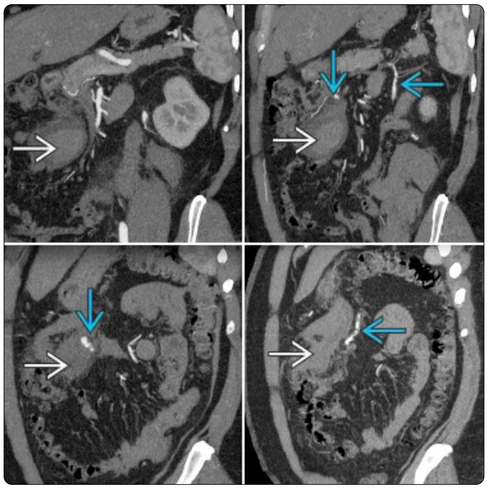


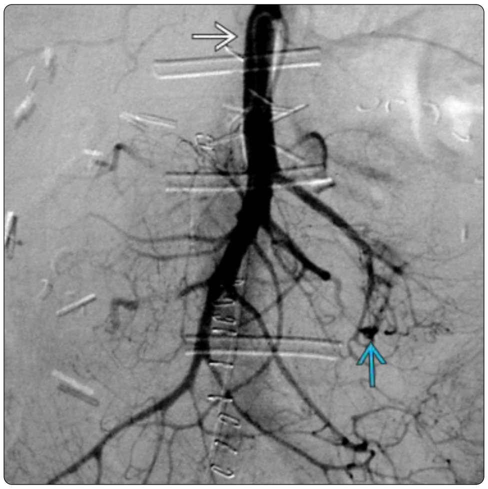
(Left) *Alternating visceral artery stenoses and dilatations* ⇨ *displayed in axial view here are the sine-qua-non of SAM.* **(Right)** *Coronal view, same case, is shown. 50% mortality is reported when SAM presents with aneurysmal rupture* ⇨ *and hemorrhage* ➡*. Intraarterial catheterization may promote further dissection. Endovascular or surgical treatment may be considered in acute hemorrhage/ischemia. Patients without hemorrhage should be treated conservatively. Prophylactic treatment is controversial.*

Segmental Arterial Mediolysis (Omental Hemorrhage)

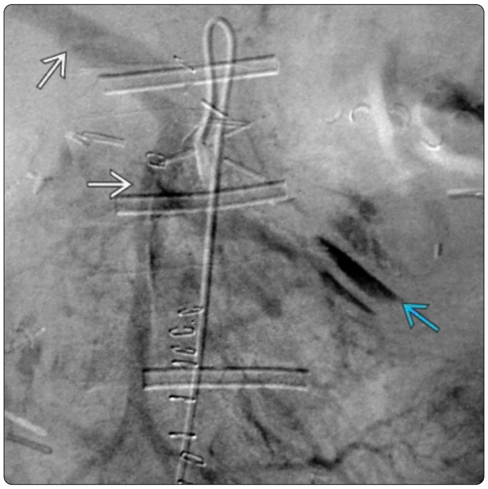


Segmental Arterial Mediolysis (Omental Hemorrhage)



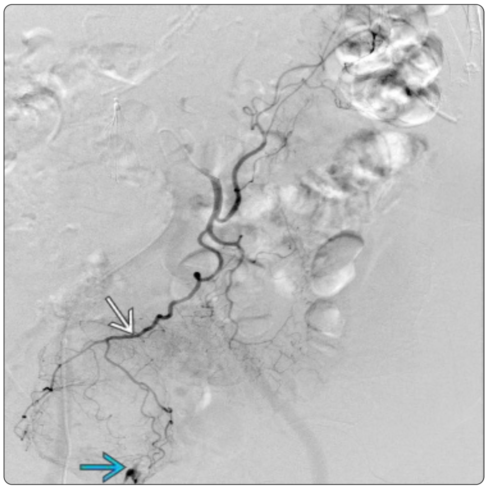


Small Bowel Surgical Anastomosis (SMA Arterial Phase)

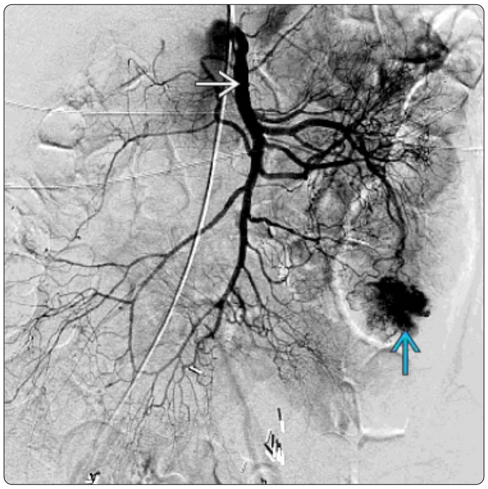


Small Bowel Surgical Anastomosis (SMA Delayed Phase)

(Left) *Superior mesenteric ➡ arteriography was performed in a patient postoperative day 2 following end-to-end bowel anastomosis. Extravasation ⇨ seen in the left mid abdomen likely from a jejunal source.* **(Right)** *Delayed view of the previous angiogram shows contrast extravasation outlining the bowel folds ⇨. Embolization of surgical anastomosis should be performed with caution as the vascular changes related to the anastomosis may increase the risk of postembolization ischemia. Note portal venous filling ➡.*

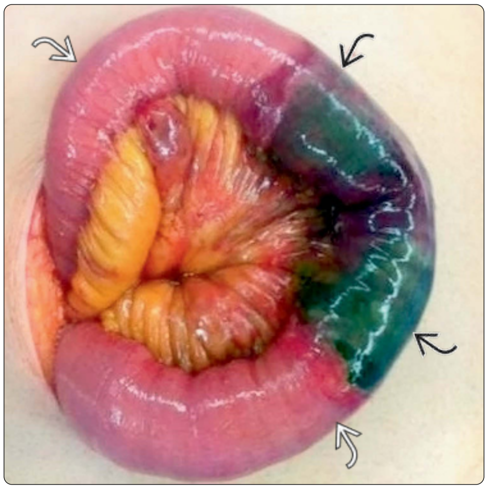


Rectal Artery Hemorrhage (Inferior Mesenteric Arteriography)

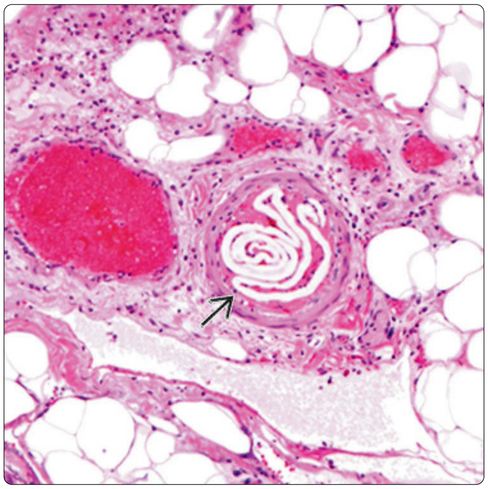


Small Bowel Tumor (Super Mesenteric Arteriography)

(Left) *In this patient with BRBPR, active bleed was found originating from a middle rectal branch ⇨ communicating with the superior rectal artery ➡. Always image the entire vascular territory.* **(Right)** *Following positive nuclear scintigraphy, diagnostic SMA angiography ➡ shows a hyperenhancing focus ⇨ (with rapid venous filling not shown) in this ED patient with active LGI bleed. "Glue" embolization was performed to halt the bleed. Subsequent surgical resection revealed this to be a small bowel GIST.*



Complication of Embolization (Segmental Jejunal Infarction)



Complication of Embolization (Segmental Jejunal Infarction)

(Left) *An intraoperative photograph following Gelfoam embolization shows an infarcted segment ⇨ of the jejunum, with adjacent normal bowel ➡. Although complications can occur following embolization for lower gastrointestinal hemorrhage, the majority are clinically insignificant.* **(Right)** *A histologic section from the infarcted jejunal segment shows Gelfoam fibers ⇨ within an arteriole. By report, ischemic complications from transcatheter embolization require therapy in only 0-6% of cases.*

KEY FACTS

TERMINOLOGY

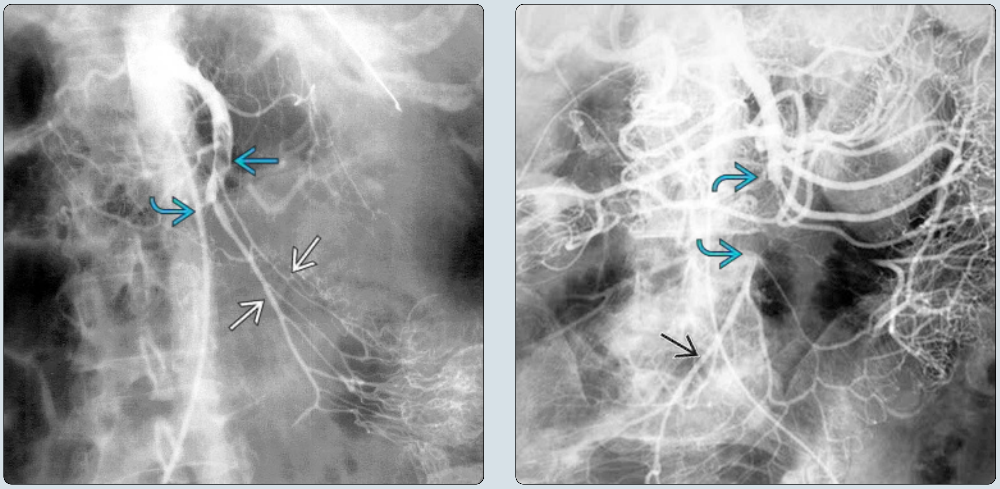
- **Acute mesenteric ischemia (AMI)**: Life-threatening emergency with 60-80% mortality
  - Mortality directly corresponds to treatment time
  - Occlusive or nonocclusive AMI (NOMI)
- **Chronic mesenteric ischemia (CMI)**: Chronic occlusion/stenosis of bowel arterial supply

PREPROCEDURE

- AMI: Endovascular vs. surgical treatment indications not well established; trend toward primary endovascular therapy when low suspicion for intestinal necrosis
- CMI: Initial endovascular stent placement (especially for poor surgical candidates); subsequent surgical options if endovascular treatment fails

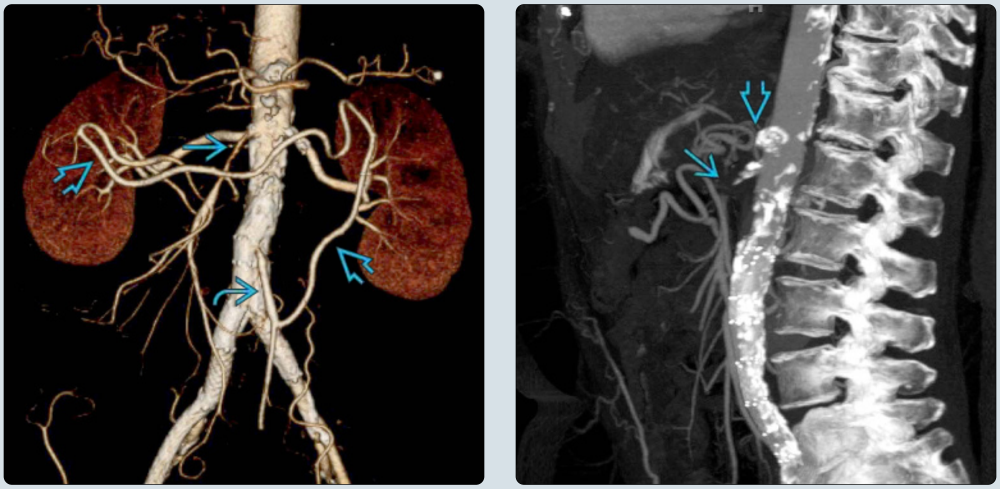
PROCEDURE

- Lateral aorta DSA evaluates celiac artery, SMA, IMA origins
  - Best view for showing origin of vessel
- AP aortic DSA evaluates aortic disease, overall mesenteric arterial, & bowel perfusion
  - Best view for showing branch vessels & collaterals
- Abnormal DSA findings in mesenteric ischemia
  - **Embolus** appears as intraluminal filling defect
  - **Thrombus** appears as tapered occlusion
  - **NOMI** appears as diffuse arterial vasoconstriction
- **AMI**: Goal is rapid reperfusion of bowel; can consider catheter-directed thrombolysis for acute embolic/thrombotic arterial mesenteric ischemia
  - Pharmacolysis: Intraprocedural bolus, power pulse
  - Pharmacolysis catheter-directed infusion
  - Catheter suction embolectomy
  - Stent deployment or angioplasty
- **SMV thrombosis**: Systemic anticoagulation
  - Consider intervention if unimproved or worsening
- **NOMI**: Intraarterial papaverine infusion
- **CMI**: Revascularization with stent
  - Single-vessel treatment usually relieves symptoms


AMI: Embolic

AMI: Embolic

(Left) *An angiogram of the superior mesenteric artery (SMA) shows an intraluminal filling defect →, with arterial occlusion ↪ just past 2 jejunal branches ➔. Acute occlusive mesenteric ischemia from arterial embolus must be treated immediately. A multidisciplinary approach involving surgery is necessary.* **(Right)** *An SMA angiogram shows acute embolic occlusion, but the embolus occludes only a short distal arterial segment ↪. The ileocolic artery ➔ fills via collateral arcades. Thrombolysis is reasonable.*


CMI: Atherosclerotic

CMI: Atherosclerotic

(Left) *A contrast-enhanced arterial-phase CT 3D reconstruction reveals a diminutive proximal portion of the SMA →. Instead, the inferior mesenteric artery (IMA) ↪ is hypertrophied, and enlarged collateral vessels ⇨ supply the SMA.* **(Right)** *The sagittal reconstruction in the same patient confirms the severity of the proximal SMA stenosis →. Unfortunately, the patent luminal diameter of the celiac artery ⇨ may not be much better.*

TERMINOLOGY

Definitions

- **Acute mesenteric ischemia (AMI)**
  - Life-threatening vascular emergency with 60-80% mortality
    - Mortality directly corresponds to diagnosis & treatment time
      - ☐ Mortality 39% when revascularization achieved < 12 h
      - ☐ Mortality 70% when time to diagnosis > 24 h
  - May be occlusive or nonocclusive in etiology
  - Clinical presentation of AMI
    - History may include atrial fibrillation, atherosclerotic disease, hypertension, myocardial infarction, postprandial pain, hypercoagulable or connective tissue disorder
      - ☐ Often elderly patients with significant comorbidities
    - Acute, severe, midabdominal pain; disproportionate to physical examination
      - ☐ May have associated nausea & gastrointestinal (GI) hemorrhage
      - ☐ May have peritoneal signs suggesting ischemia
    - Laboratory data: Leukocytosis, lactic acidosis, elevated liver enzymes
- **Occlusive AMI**
  - **Arterial embolism**
    - Cause of AMI in up to 50% of cases
    - Superior mesenteric artery (SMA) very susceptible because of high flow & acute takeoff from aorta
    - 50% of emboli lodge 6-8 cm beyond SMA origin, just distal to middle colic origin
      - ☐ Emboli lodge at bifurcation points, more distally as arterial caliber decreases
    - Etiology often from cardiac sources: Risk factors include acute myocardial infarction, arrhythmia, ventricular aneurysm, or valvular disease
    - Lack of collaterals results in poor distal SMA flow
    - Inferior mesenteric artery (IMA) less common site of occlusion due to lower flow & smaller lumen
  - **Arterial thrombosis**
    - Cause of AMI in ~ 25% of cases
    - Acute thrombosis of preexisting stenosis, occurring near SMA origin
    - Associated with previous postprandial pain & intestinal angina
    - Collateral vessel may be present due to chronic stenosis
    - Onset may be less acute vs. arterial embolism
    - Often worse prognosis than arterial embolism because of more proximal occlusion
  - **Aortic dissection**
    - Cause of AMI in < 5% of cases
    - Dissection flap extends into SMA
  - **Miscellaneous etiologies**
    - Trauma, retroperitoneal fibrosis, fibromuscular dysplasia, segmental arterial mediolysis, & vasculitis
- **Nonocclusive AMI (NOMI)**
  - Cause of AMI in 25% of cases
  - Associated with prolonged hypotensive event or vasopressors (e.g., digitalis, dopamine)
  - Other causes of NOMI include drugs (cocaine, digitalis), recent coarctation repair, & vasculitides
  - Diffuse vasospasm throughout SMA territory is characteristic
  - Delayed filling of superior mesenteric vein (SMV) occurs on imaging
- **Mesenteric venous thrombosis**
  - Cause of AMI in 5-10% of cases
    - May involve SMV &/or smaller venous branches
  - Associated with hypercoagulability, trauma, abdominal surgery, neoplasm, inflammatory bowel disease, oral contraceptives, or sepsis
- **Chronic mesenteric ischemia (CMI)**
  - a.k.a. intestinal angina
  - Chronic occlusion/stenosis of bowel arterial supply
    - Historically defined as occlusion/stenosis of ≥ 2 of 3 major mesenteric vessels (i.e., celiac, SMA, IMA)
    - Increasingly recognized that occlusion/stenosis of 1 of 3 major mesenteric vessels can result in CMI
  - Progression from CMI to AMI has > 50% mortality
  - Clinical presentation of CMI
    - Recurrent episodes of postprandial pain (dull, cramping) beginning shortly after eating & lasting 1-2 h in duration
    - 80% association with weight loss due to food aversion/fear of eating
    - Nonspecific nausea, vomiting, diarrhea
    - Relates to digestive demand for increased blood flow; perfusion restricted by occlusive process
  - **Atherosclerotic CMI**
    - Occurs more frequently in older women
    - Associated with peripheral vascular disease, coronary artery disease, smoking
    - May consider endovascular stent placement as 1st-line therapy
      - ☐ Especially for poor surgical candidates
      - ☐ Surgical options remain if endovascular treatment fails
  - **Median arcuate ligament syndrome**
    - Abdominal pain attributed to compression of celiac artery or ganglion by median arcuate ligament (fibrous arch formed by left & right diaphragmatic crura)
    - More common in women ages 20-40 yr
    - Symptoms may involve celiac ganglion compression
      - ☐ Worsened by stent placement
      - ☐ Should be surgically treated
    - Debatable whether this is CMI variant
  - **Other causes of CMI**
    - Arterial dissection, fibromuscular dysplasia, radiation

PREPROCEDURE

Indications

- **AMI**
  - Various endovascular treatment options, dependent on etiology

    - Vasodilator administration, pharmacological/mechanical thrombolysis, angioplasty, stenting
  - **Occlusive etiology**
    - Endovascular vs. surgical treatment indications not well established; remains controversial
      - ☐ Recent reports trending toward primary endovascular therapy for patients with low suspicion for intestinal necrosis
      - ☐ Consider endovascular treatment for patients with evidence of early bowel ischemia
      - ☐ Patients with peritoneal signs do not necessarily have improved mortality when surgery initially performed
      - ☐ Multidisciplinary input (e.g., surgery, vascular surgery, critical care) advisable
    - Elevated white blood cell count & peritoneal signs suggest urgent aggressive therapy (surgical or endovascular) necessary
  - **NOMI**
    - 1st treat underlying cause of hypotension
    - Consider catheter-directed intraarterial infusion of papaverine into SMA (typically 24-48 h)
  - **Mesenteric venous thrombosis**
    - Asymptomatic: Initiate systemic anticoagulation & supportive care
    - Worsening clinical condition: Consider endovascular therapies
    - Infarcted bowel: Consider surgical resection & thrombectomy
- **CMI**
  - Presence of ischemic symptoms
    - Atherosclerotic etiology may improve with stent
    - Median arcuate ligament syndrome should **not** be initially treated with PTA/stent
      - ☐ Diagnostic lateral arteriography with inspiration & expiration may assist with diagnosis
  - Controversial in asymptomatic patients
    - Relative indication: Asymptomatic stenotic/occlusive disease of all 3 mesenteric arteries
    - Isolated single vessel disease most often does not require intervention
    - Patients undergoing aortic reconstruction for aneurysmal or occlusive disease may benefit from endovascular revascularization

Contraindications

- Presence of advanced ischemic symptoms with peritoneal signs &/or lactic acidosis
  - Signs of impending bowel infarction
    - Consider urgent exploratory laparotomy
    - Consider combined procedure in hybrid operating room
      - ☐ Initiate endovascular treatment; if unsuccessful, convert to open laparotomy
  - Definitive evidence of bowel infarction
    - Surgical bowel resection required
- Contraindication to contrast administration
  - Renal insufficiency; anaphylaxis to contrast media
- Thrombolysis contraindication: Active bleeding, recent surgery, recent stroke/active intracranial process
- Vasodilator (e.g., papaverine) contraindication: Administration relatively contraindicated in complete heart block
  - Other relative contraindications: Simultaneous administration of alkaline substances, narrow angle glaucoma, severe cardiac or liver disease

Preprocedure Imaging

- CECT/CTA
  - 1st diagnostic study of choice for AMI
  - Differentiates AMI etiology, permits treatment planning
    - Embolus: Central convex filling defect in SMA, 3-8 cm distal of SMA origin
    - Atherosclerotic stenosis/occlusion of SMA takeoff
    - Thrombosis of SMA: Arterial nonopacification
    - Aortic dissection: Identifies extent of flow through true & false lumen to distal mesenteric branches
    - Identifies SMV thrombosis: Low-attenuation filling defect in SMV accompanied by mural enhancement
  - Includes benefits of nonenhanced CT
- NECT
  - Early: Bowel dilatation, wall thickening, ascites, mesenteric edema
    - May represent reversible ischemic changes
  - Late: Pneumatosis intestinalis, pneumoperitoneum, intravascular gas
    - Signs of bowel infarction
  - NECT may demonstrate atherosclerotic disease
- MRA
  - Similar to CTA regarding proximal arterial & venous disease but often limited by availability, ability to evaluate small vessels & bowel, & increased time required to obtain images
  - Can use MR techniques to optimize imaging with food challenge
    - Phase-contrast imaging/MR oximetry can evaluate oxygenation of SMV blood
    - Useful in suspected CMI
- DSA
  - Traditional gold standard for diagnosis
    - CT/MR now preferred as initial imaging modality for evaluating mesenteric ischemia
  - Consider DSA if equivocal CTA/MRA findings
    - Used when intervention anticipated
    - Must consider time restraints in suspected AMI
- Duplex ultrasound
  - Readily available to screen for CMI
  - SMA: Fasting state shows high-resistance waveform; postprandial shows increased end-diastolic velocity (EDV)
  - Celiac: High EDV with little increase from fasting to postprandial states
  - Significant stenosis: Increased peak systolic velocity & EDV
  - Retrograde flow: Suggests occlusion of vessel origin

Getting Started

- Things to check
  - Laboratory studies
    - Complete blood count, comprehensive metabolic panel, serum lactic acid, coagulation panel
  - History

    - Time of onset of pain, diarrhea, hematochezia
    - Prior embolic disease; present in 1/3 of patients with embolic AMI
- Medications
  - Fibrinolytic or thrombolytic medications
    - Tissue plasminogen activator (tPA)
    - Recombinant tPA
      - Alteplase [Activase (Genentech; South San Francisco, CA)]
      - Reteplase [Retavase (EKR Therapeutics; Bedminster, NJ)]
      - Tenecteplase [TNKase (Genentech)]
  - Heparin
    - Various intraprocedural administration regimens
      - Bolus dose of 2,500-5,000 U; followed by infusion of 1,000 U/h
      - Loading dose of 50-100 U/kg; followed by continuous infusion of 15-25 U/kg/h
  - Vasodilators
    - Papaverine
      - Typical dosage into SMA: 45- to 60-mg bolus, then 30- to 60-mg/hr infusion
      - Nonxanthine phosphodiesterase inhibitor
      - Relaxes smooth musculature of larger arteries
    - Nitroglycerin
      - Typical bolus dose of 100 μg nitroglycerin
      - Prevents/treats catheter-induced vasospasm
- Equipment list
  - Catheters & sheaths
    - Vascular access sheath
      - Permits catheter exchanges as necessary
      - Reduces local complications at access site
      - Various available sheath sizes; choice depends on catheter/device used for procedure
    - Guiding sheath
      - Typically 6- to 8-Fr sizes
      - Straight configuration [e.g., Destination, Pinnacle (Terumo; Somerset, NJ)]
      - Curved configuration (e.g., Ansel, Balkin)
    - Flush catheter
      - Pigtail, OmniFlush (AngioDynamics; Latham, NY)
    - Selective catheters (various designs)
      - Kumpe, Cobra (forward-facing catheters)
      - Simmons, Mickaelsson (reverse-curve catheters)
    - Specialty catheters
      - Angioplasty (PTA) balloon catheter
  - Guidewires
    - Initial "starting" 0.035" guidewire (3-J tip)
    - Angled or straight-tipped hydrophilic guidewire
      - Useful for crossing stenosis/occlusion
      - Useful for selective arterial catheterization
    - Stiff guidewire
      - e.g., Amplatz, Lunderquist, Rosen
      - For stability when advancing devices/sheaths
  - Stents
    - Noncovered balloon mounted
      - Typically more precise placement
      - Various proprietary options, diameters, lengths
      - Usually preferred for visceral arteries
    - Noncovered self-expanding
      - May require postdeployment PTA
    - Covered balloon mounted/self-expanding
      - Not typically used in visceral artery ischemia interventions; risk of covering branch vessels
  - Thrombolysis equipment
    - Infusion catheter: Typically have multiple side holes/slits; various catheter/infusion lengths
      - Various proprietary therapeutic infusion systems
      - Used for pharmacologic thrombolysis
    - EkoSonic system (Ekos; Bothell, WA)
      - Ultrasound-accelerated infusion catheter
    - Mechanical thrombectomy devices
      - Thrombolysis via clot fragmentation/aspiration
      - Infrequently used in mesenteric ischemia

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Arterial access via femoral or brachial artery
    - Consider ultrasound guidance if thrombolysis planned
      - Minimizes number of puncture attempts
    - Consider brachial access if preprocedure imaging shows acutely angled, caudal orientation of SMA or aortoiliac occlusion

Procedure Steps

- **General**
  - Obtain arterial access
  - Introduce vascular access sheath & guidewire
    - Typically femoral artery access
    - Consider brachial artery access for steep SMA angle with heavily calcified occlusion or aortoiliac occlusion
  - Introduce flush catheter (e.g., pigtail)
    - Position catheter side holes at T12 vertebral level
  - Obtain abdominal aortic DSA: AP & lateral
    - AP view evaluates for aortic disease, mesenteric arterial distribution, & overall bowel perfusion
      - Best view for showing branch vessels & collaterals
    - Lateral view evaluates celiac, SMA, & IMA origins
      - Best view for showing origin stenosis/occlusion
    - Late-acquisition images utilized to assess SMV
  - Selectively catheterize SMA
    - SMA origin/proximal vessel orientation determines optimal catheter for engaging artery
      - Forward-facing catheter for horizontally oriented artery
      - Reverse-curve catheter for acutely angled artery; also more optimal for engaging stenotic origin
    - Consider placing guiding sheath to SMA origin (e.g., 7-Fr Ansel), with coaxial selective catheter if planning intervention
      - Sheath facilitates pharmacomechanical thrombolysis, suction embolectomy, & stenting
  - Inject contrast, obtain DSA images
    - Initial SMA angiography can be done at a rate of 3-6 mL/sec for a total volume of 30-45 mL
    - Extended imaging time for 30-40 sec will allow visualization of mesenteric veins
  - Review DSA images to confirm/exclude abnormalities
    - **Embolus** appears as intraluminal filling defect

        - ☐ Usually rounded, well defined; may see convex meniscus at interface with contrast
        - ☐ Typically located beyond SMA origin, where artery tapers; may lodge at/extend into branch vessel
        - ☐ Collateral flow unlikely with acute embolism
    - **Thrombus** appears as tapered occlusion
        - ☐ Located at or near SMA origin
        - ☐ May have associated collaterals; represents acute thrombotic occlusion of chronic stenosis
    - **Dissection** appears as linear defect
        - ☐ May be seen best in 1 plane
    - **NOMI** appears as diffuse arterial vasoconstriction
        - ☐ May have alternating areas of segmental constriction; appears as string of sausages
        - ☐ Reduced opacification of bowel parenchyma
        - ☐ Normal mesenteric venous phase
  - ○ Proceed with intervention if appropriate
- **Acute embolic or thrombotic SMA occlusion**
  - ○ Primary goal: Rapidly establish SMA patency; removal of all distal branch thrombus may not be possible
    - Distal embolic protection devices (EPDs) may be considered, but reports discuss endovascular treatment without EPDs
    - Initiate systemic anticoagulation
    - Selectively catheterize thrombosed SMA, typically over hydrophilic Glidewire
  - ○ **Thrombolysis: Intraprocedural catheter directed**
    - Confirm SMA catheter location with hand contrast injection
    - Hand bolus thrombolytic (tPA, 4-10 mg) into thrombus (distal to proximal) via catheter
    - Alternatively, power pulse thrombolysis has been described
    - While thrombolytic dwells, consider additional appropriate therapy
  - ○ **Catheter suction embolectomy**
    - Exchange Glidewire for stiff guidewire
    - Advance large-caliber (e.g., 8-Fr size) sheath into SMA
        - ☐ Position tip of sheath adjacent to embolus
    - Aspirate catheter using large-capacity syringe
  - ○ **Stent deployment**
    - Used to treat proximal SMA lesion prior to infusion thrombolysis or treat lesion uncovered by thrombolysis
    - Consider use to emergently restore patency to occluded SMA in critical (current/pending) clinical situation
        - ☐ Caution: Stent deployment can inadvertently occlude branch vessels if deployed in false lumen or displace thrombus into branch vessels; consider clinical situation prior to use
    - Determine desired diameter & length of stent
        - ☐ Perform DSA via guiding sheath or with simultaneous contrasting injection via catheter advanced into mid SMA
        - ☐ Determine appropriate stent design (self-expanding vs. balloon expandable, covered vs. noncovered); use caution not to cover branch vessels with covered stent
    - Predilation with 3- to 4-mm balloon may be necessary to advance stent into place
  - ○ **Thrombolysis: Catheter-directed infusion**
    - Used if symptoms < 12 h in duration
    - May not restore arterial flow quickly enough to prevent bowel infarction
    - Via SMA-guiding catheter, advance coaxial infusion catheter over guidewire into SMA
        - ☐ Consider multiple sidehole or EkoSonic infusion catheter
    - Initiate continuous infusion of thrombolytic agent (consider initial bolus dose)
        - ☐ Typical initial bolus: 5-20 mg of tPA
        - ☐ Typical infusion rate: 0.5-1.0 mg tPA/h
    - Ensure adjuvant heparinization
    - Monitoring in ICU during thrombolysis
        - ☐ Evaluation for any developing peritoneal signs
        - ☐ Assess for any bleeding at access site
        - ☐ Check fibrinogen values q 4 h; fibrinogen level should remain > 100 mg/L
    - Assess thrombolysis progress with DSA (e.g., 4-12 h)
        - ☐ Contrast injection via guiding sheath
    - If successful thrombolysis results & underlying stenosis identified, perform PTA/stenting
    - Strongly consider surgery if no improvement in 4 h or peritoneal signs develop
- **Nonocclusive mesenteric ischemia**
  - ○ Selectively catheterize SMA
  - ○ Initiate papaverine infusion via selective catheter
    - Dilute papaverine in normal saline (1 mg/mL)
    - Administer bolus of 45-60 mg followed by continuous infusion of 30-60 mg/h
    - Adjust infusion based on clinical response
        - ☐ Typically requires at least 24-h infusion
    - Evaluate papaverine efficacy within first 12-24 h after initiating treatment
        - ☐ Obtain DSA via infusion catheter
    - D/C papaverine infusion if clinical/angiographic improvement
    - Continue to infuse catheter with normal saline for 30 min after ceasing papaverine infusion
        - ☐ Repeat DSA; exclude recurrent vasoconstriction
    - With persistent vasospasm, can repeat cycle every 24 h up to 5 days
  - ○ Alternative: High-dose prostaglandin administration
    - Dose: 0.01-0.30 μg/kg/min for up to 5 days
  - ○ Consider adjunctive nifedipine (10-20 mg po q 6 h)
- **SMV thrombosis**
  - ○ Conservative management is 1st-line treatment
    - Anticoagulation, supportive care, hydration
  - ○ Consider endovascular treatment if no improvement or symptoms worsen
    - Direct pharmacologic thrombolysis, mechanical thrombectomy, PTA, & stent placement via
        - ☐ Right internal jugular, transhepatic venous access (TIPS-like approach to SMV)
        - ☐ Percutaneous transhepatic venous access
        - ☐ Direct SMV access
    - Indirect pharmacologic thrombolysis via infusion catheter placed in SMA
- **Aortic dissection**: Can cause mesenteric ischemia by various mechanisms

  - Compression of true lumen/branch vessels by enlarging false lumen
    - Can place aortic endograft in true lumen
      - Decreases perfusion in false lumen
      - Improves SMA perfusion via true lumen
  - Extension of aortic dissection flap into SMA
    - Can place noncovered stent in SMA
      - Compresses dissection flap against arterial wall; improves SMA perfusion
  - Hypoperfusion of SMA arising from false lumen
    - May require surgical fenestration/revascularization
- **CMI**
  - Confirm stenosis/occlusion with aortic DSA
    - Pressure gradients may be obtained as needed; suggested peak systolic gradients
      - > 20 mm Hg significant
      - 10-20 mm Hg borderline
      - < 10 mm Hg not significant
  - Selectively catheterize SMA origin
    - Advance guidewire across stenosis/occlusion
    - Place guiding sheath in SMA origin
      - May require stiff 0.035" guidewire for support
  - Systemically heparinize patient before intervention
    - Current trend toward stenting rather than PTA
      - Better outcomes for stenoses/total occlusions
  - Severe stenosis may require PTA before stenting
    - Perform PTA (4 mm) via sheath
  - Introduce balloon-mounted stent via sheath
    - Bare metal stents (BMS) most often used
    - Recent study comparing covered stents vs. BMS found covered stent had ↑ patency (92% vs. 52%) & ↓ symptom recurrence (92% vs. 50%) at 3 yr
  - Position stent bridging stenosis; confirm position with DSA via guiding sheath prior to deployment
    - Stent should extend slightly into aortic lumen
    - Deploy stent
  - Obtain completion DSA, document results, & exclude complications
  - Single-vessel (SMA) revascularization usually sufficient to relieve symptoms
  - IMA revascularization & PTA/stenting have been described, as appropriate for individual case

Alternative Procedures/Therapies

- Surgical
  - Surgical exploratory laparotomy
  - Emergent surgical embolectomy or bypass
  - Surgical bowel resection necessary for any infarcted segments
    - May require "2nd look" operation to identify additional ischemic bowel needing resection
  - CMI: Mesenteric artery bypass grafting
  - Median arcuate ligament syndrome: Surgical decompression; may be followed by angiography to evaluate resolution or consider PTA of residual stricture (no stent)
- Other
  - Start medical treatment immediately if mesenteric ischemia suspected
    - Fluid resuscitation, broad-spectrum antibiotics, nasogastric tube decompression, anticoagulation, & avoidance of vasopressor medications

POST PROCEDURE

Things to Do

- ICU: Admit all patients for clinical monitoring
  - NPO or on clear liquids for minimum of 12 h
  - Monitor for lactic acidosis (normal: 0.2-2.2 mmol/L)
    - Levels > 6.0 mmol/L suggest compromised bowel
  - Consider total parental nutrition early in treatment
- Reperfusion injury
  - Consider administering IV glucagon
    - Dose: 1 µg/kg/min titrated up to 10 µg/kg/min
    - Causes intestinal vasodilatation/hypotonicity
      - Reduces oxygen demand
  - Allopurinol/enalapril act as free radical scavengers
    - May decrease risk of reperfusion injury
- Anticoagulation: Titrate IV heparin to partial thromboplastin time of 60-80 sec
  - In immediate postprocedure period, avoid low-molecular-weight heparin
    - Long half-life may limit repeat interventions
- Antibiotics: Mesenteric venous thrombosis can injure intestinal mucosa; raises risk of septic thrombophlebitis from gram-negative & anaerobic bacteria
  - Consider broad-spectrum IV antibiotic therapy
    - Empiric piperacillin/tazobactam (Zosyn)
      - Dose: 3.375 g
    - Consider addition of metronidazole (Flagyl)
      - Dose: Load with 15 mg/kg over 1 h; subsequent doses of 7.5 mg/kg every 6-8 h
    - Consider addition of levofloxacin (Levaquin)
      - Dose: 500 mg every 24 h
- Antiplatets: Carefully manage patients with stents
  - Initiate antiplatelet therapy
    - Aspirin: 81-325 mg/day for life
    - Clopidogrel: 300 mg loading dose then 75 mg/day
      - Continue for 3-6 months or indefinitely
- Consult consideration: Gastroenterology
- Posthospitalization clinical follow-up
  - 30-day outpatient clinic visit, with CTA
    - Obtain CTA or duplex ultrasound to assess vessel patency
    - Assess resolution of symptoms, weight gain if CMI
  - Then 6-, 12-month CTA/duplex ultrasound to exclude restenosis

Things to Avoid

- Avoid hypotensive episodes related to vasodilator infusion; maintain close hemodynamic monitoring
  - Can treat hypotension with cardiotonic agents
    - Dopamine (2-5 µg/kg/min)
    - Dobutamine (0.1-1.0 µg/kg/min)
  - Avoid vasopressin/α agonists
    - May worsen mesenteric vasoconstriction

OUTCOMES

Problems

- High mortality persists in AMI
  - Reported rates of 60-80%
  - Lack of prospective, randomized controlled trials assessing optimal means of diagnosis & therapy

Complications

- Most feared complication(s)
  - Ischemic bowel infarction
- Immediate/periprocedural complication(s)
  - Postrevascularization reperfusion syndrome
    - Reperfused ischemic cells may lose membrane integrity, release cellular proteins
      - Toxic reactive oxygen metabolites generated
    - Leads to bowel inflammation
      - Causes compromised bowel mucosa
      - Increased microvascular permeability
      - Can result in transmural infarction
  - Access site complications
    - Hematoma, pseudoaneurysm, iatrogenic arteriovenous fistula formation
      - Thrombolysis/anticoagulation increases risk
  - Vasodilator related
    - Systemic hypotension if infusion catheter dislodges; intraaortic administration occurs
  - Thrombolysis related
    - Hemorrhagic complications
      - Gastrointestinal/intraperitoneal hemorrhage
      - Stroke
  - Angioplasty related
    - Arterial dissection/rupture
    - Distal embolization
- Delayed complication(s)
  - Contrast-induced nephropathy
  - Stenotic/occlusive related complications
    - Device-related complications
      - Stent fracture with thrombosis/occlusion
    - Neointimal hyperplasia
      - In-stent stenosis/thrombosis

Expected Outcomes

- **AMI: Endovascular revascularization**
  - Clinical benefits range from 40-90%; decreased mortality, inpatient duration, need for total parenteral nutrition, & bowel resection rates
  - Technical success rates range from 80-100%
    - Endovascular outcomes appear to be comparable with surgery in appropriately selected patients
      - Better outcomes in treating SMA embolus vs. SMA thrombosis
    - Thrombolysis shown to be effective in small studies
      - 90% technical success; 70% clinical success
    - Vasodilators have reported efficiency of 70-80%
      - No variability based on type of vasodilator used
  - Post-PTA/stenting restenosis rate: 15-25% at 1 year
- **CMI: Endovascular revascularization**
  - PTA &/or stenting shown to be beneficial in CMI
    - Technical success reported at 71-97% of patients
    - Clinical success 81-88%
    - Recurrence rate 11-17%
  - Endovascular vs. open surgical revascularization (limited data)
    - Surgery associated with decreased vessel restenosis but increased periprocedural morbidity

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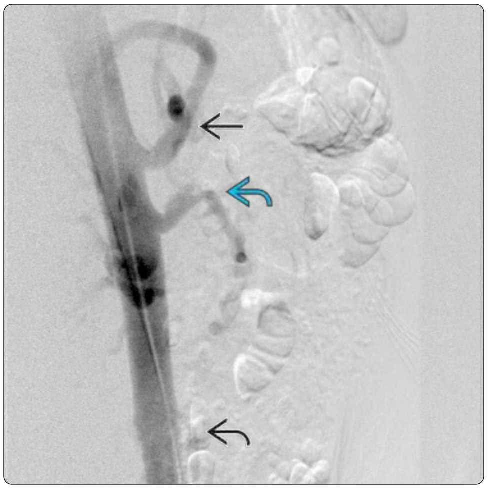
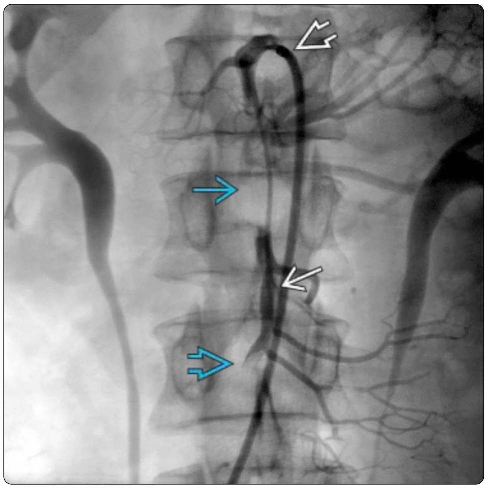
AMI: Dissection of SMA (Initial SMA Angiogram, Lateral)

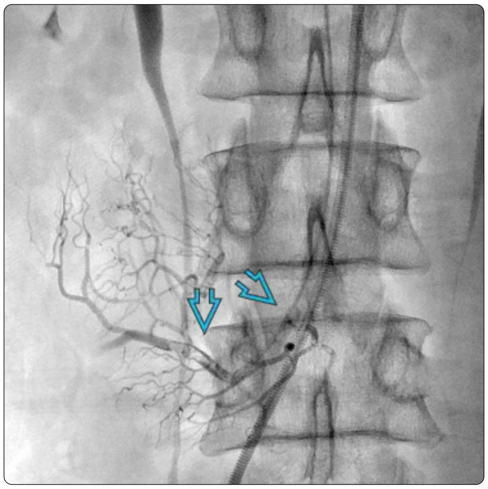


AMI: Dissection of SMA (Initial SMA Angiogram, Anterior)

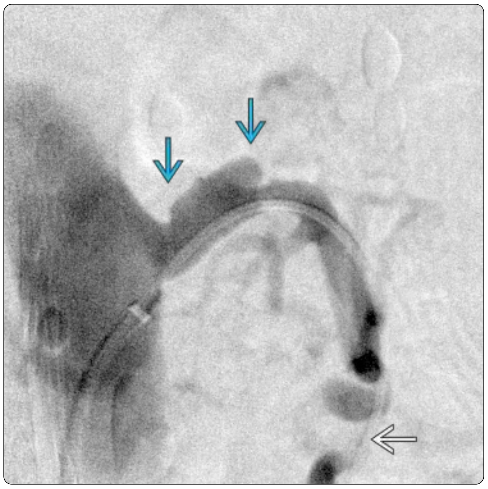


(Left) *A 54-year-old man had acute onset of abdominal pain. 5 h later, exam revealed leukocytosis and pain out of proportion to exam without rebound tenderness. CECT showed SMA dissection and small bowel dilation with wall thickening. Proximal SMA ↶ is irregular on lateral aortography. Celiac artery ← and inferior mesenteric artery (IMA) ↶ are patent.* **(Right)** *Simultaneous contrast injection through guide catheter ➡ and selective 4-Fr catheter ➡ confirmed mid-SMA dissection →, separate distal SMA convex defect ⇨.*

AMI: Dissection of SMA (Catheter Delivery of Thrombolytic)

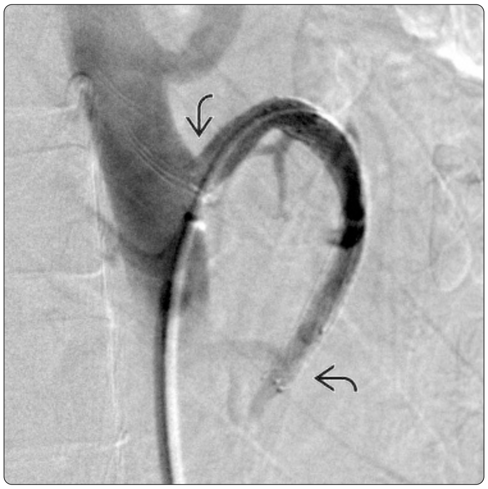


AMI: Dissection of SMA (Proximal SMA)

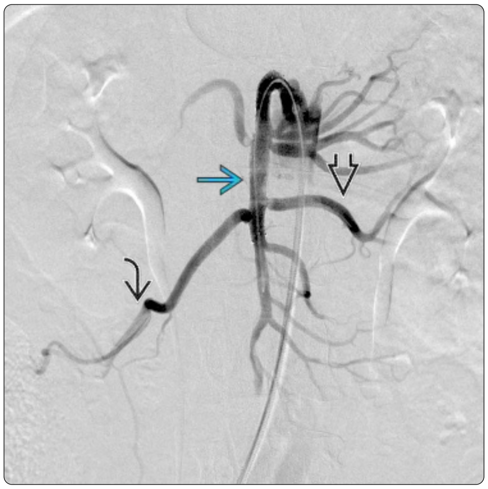


(Left) *After confirmation that the 4-Fr catheter was within the true lumen, the catheter was further advanced into the distal SMA & ileocolic branch. Hand contrast injections showed a filling defect ⇨ that appeared acute in nature. Four mg tPA was injected into the filling defect and left to dwell.* **(Right)** *A magnified view of the proximal SMA shows the dissection flap → and its proximal extent. Earlier mid-SMA contrast injections confirmed that the catheter ➡ traversed through the true lumen. Never lose true-lumen access once achieved.*

AMI: Dissection of SMA (Stent Deployment)

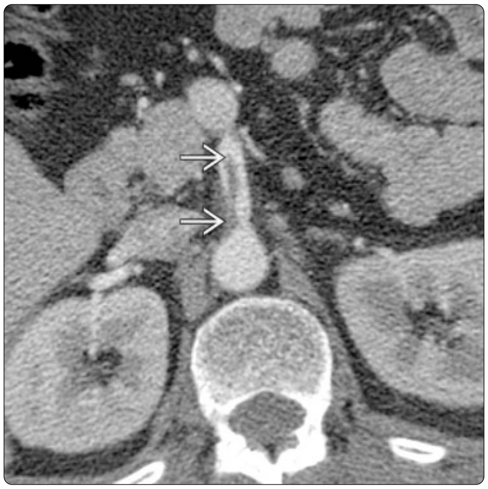


AMI: Dissection of SMA (Final Post Stent Deployment DSA)

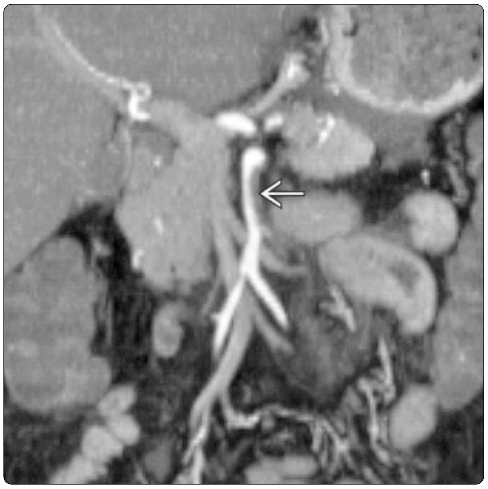


(Left) *After real-time review of images with a vascular surgeon, a decision was made to attempt rapid restoration of proximal SMA flow by tacking down the dissection flap with (2 overlapping) noncovered, self-expanding stents ↶. Not without risk, stent deployment can inadvertently occlude SMA branches supplied via the false lumen.* **(Right)** *Mid-SMA →, midjejunal ⇨, and right colic artery ↶ flow was restored. Ileocolic flow improved (subsequent images). IV heparin was started, and the patient recovered completely.*

(Left) *A patient with acute onset of severe abdominal pain shows an intraluminal filling defect ➡ proximally in the SMA, which is consistent with an embolus. Arterial embolus is the cause of AMI in almost 50% of individuals and usually involves the SMA.* **(Right)** *Coronal CT reconstruction also shows the embolus ➡. Roughly 50% of emboli lodge a few centimeters beyond the SMA origin, after the middle colic artery takeoff or more distally as the arterial caliber decreases.*

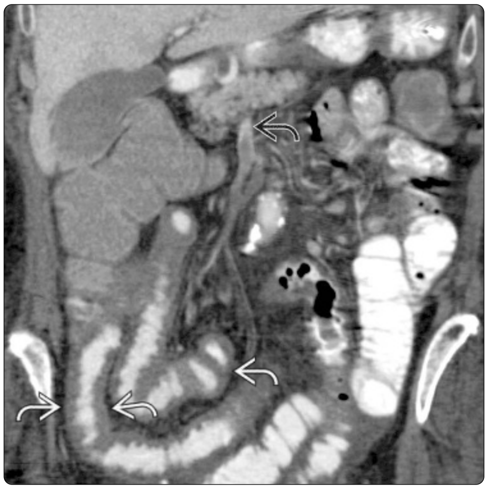


AMI: Embolus (CECT of SMA)

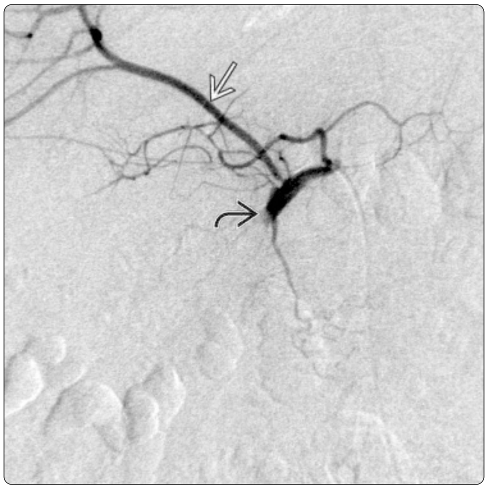


AMI: Embolus (CECT of SMA)

(Left) *CT shows abnormally dilated bowel loops with wall thickening ↪ with profound abdominal pain. There is a small amount of intravascular contrast in the proximal SMA ↷, but the remainder of the artery is nonopacified.* **(Right)** *Embolic occlusion ↷ of the entire SMA occurred distal to a replaced right hepatic artery ➡. Emergency surgical revascularization, possibly including bowel resection, must be strongly considered in cases of impending (lactic acidosis or peritoneal signs) or actual bowel infarction.*

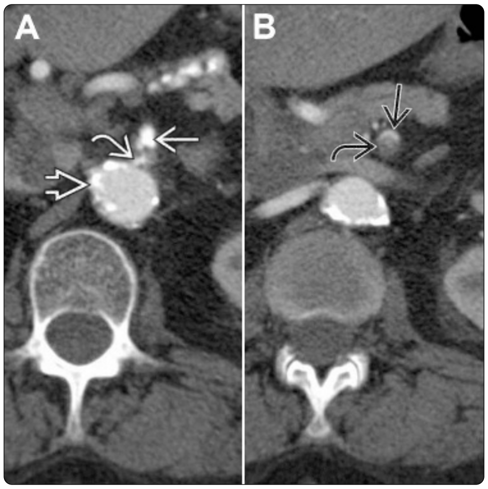


AMI: Massive Embolic SMA Occlusion (Coronal CECT)

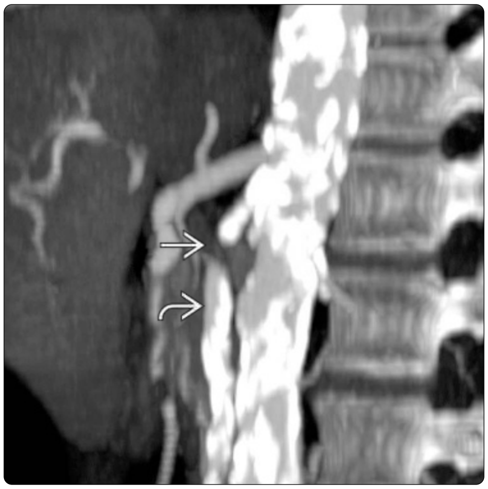


AMI: Massive Embolic SMA Occlusion (DSA of SMA)

(Left) *A patient with severe abdominal pain has (A) calcified plaque in the aorta ➩ and proximal SMA ➡. Contrast only opacifies a portion ↪ of the SMA origin. (B) More distally, an intraluminal filling defect ↷ is seen in the SMA with a meniscus of contrast ⇨ where the artery is reconstituted via collaterals.* **(Right)** *The proximal SMA is occluded ➡ with distal reconstitution ↪. Because of longstanding stenotic disease, sufficient collaterals reconstituting the distal SMA had developed.*

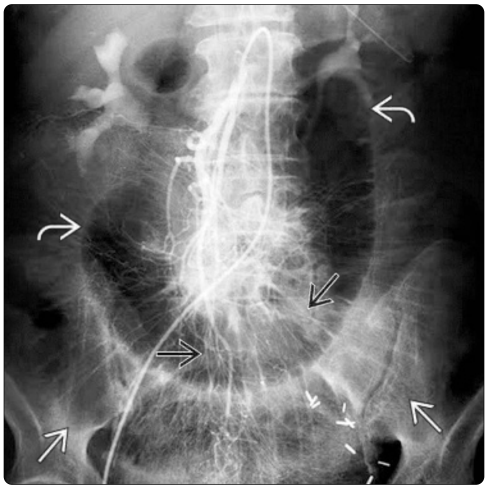


AMI: Thrombotic SMA Occlusion (Axial CECT)

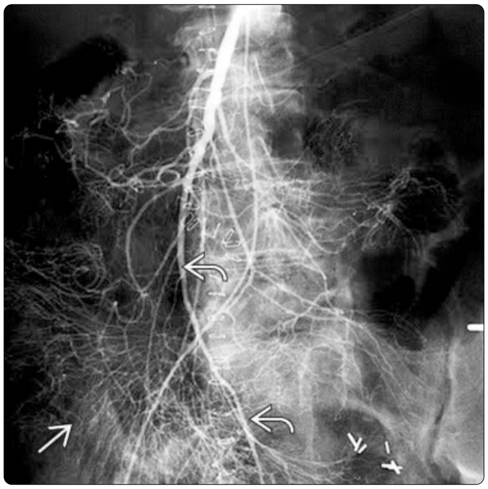


AMI: Thrombotic SMA Occlusion (CECT 3D Reformation)

AMI: Nonocclusive Mesenteric Ischemia (Superior Mesenteric Arteriogram)

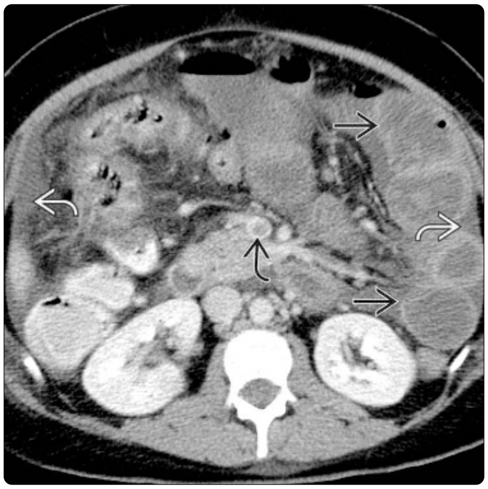


AMI: Nonocclusive Mesenteric Ischemia (Following Papaverine Infusion)

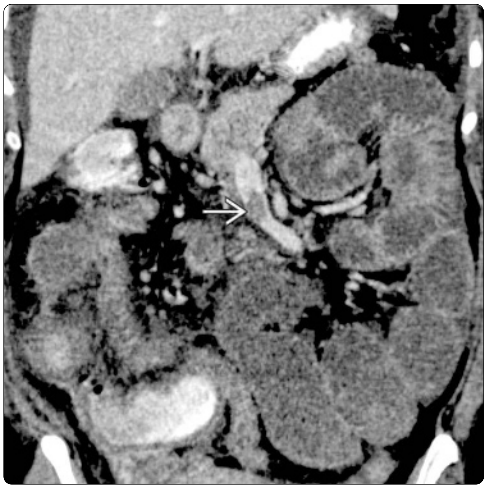


(Left) *A patient with sepsis and profound hypotension was treated with vasopressors and later developed severe abdominal pain. Diffuse, severe vasoconstriction ⇨ is present, with almost no bowel parenchymal opacification ➡ and marked bowel dilatation ➦. The findings are consistent with nonocclusive mesenteric ischemia.* **(Right)** *Papaverine infusion via the SMA catheter was begun at a rate of 50 mg/h. Repeat angiography 36 hours later shows significant improvement in the vasoconstriction ➦ and the bowel opacification ➡.*

AMI: Mesenteric Venous Thrombosis (Initial CECT Evaluation)

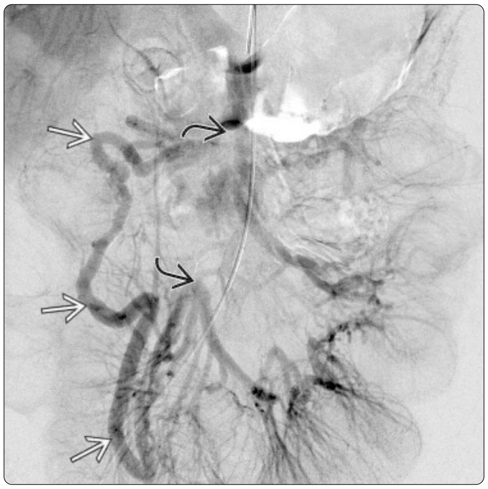


AMI: Mesenteric Venous Thrombosis (Initial CECT Evaluation)

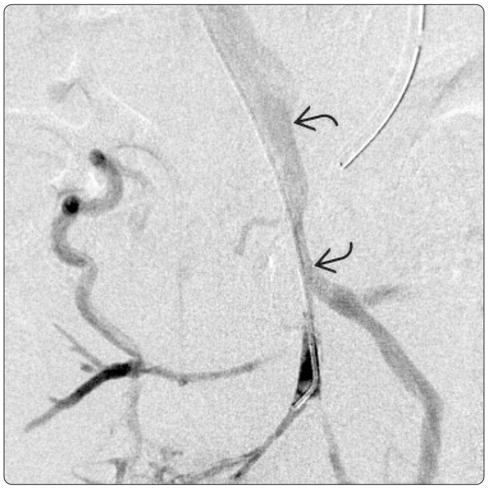


(Left) *An axial CECT in a young woman on oral contraceptives who presented with worsening abdominal pain and guaiac + stools shows dilated bowel loops ⇨, free intraabdominal fluid ➦, and an intraluminal filling defect ↪ in the superior mesenteric vein. The findings are consistent with mesenteric venous thrombosis.* **(Right)** *The coronal reconstruction also shows the superior mesenteric vein thrombus ➡. Conservative management with hydration and anticoagulation is usually the initial treatment for this clinical entity.*

AMI: Mesenteric Venous Thrombosis (DSA Prior to Intervention)



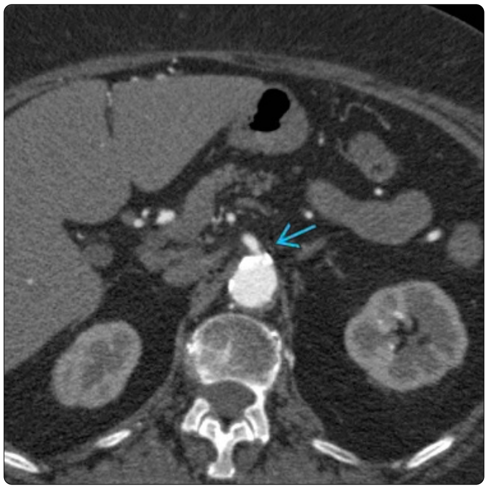
AMI: Mesenteric Venous Thrombosis (Transcatheter Venous Thrombolysis)



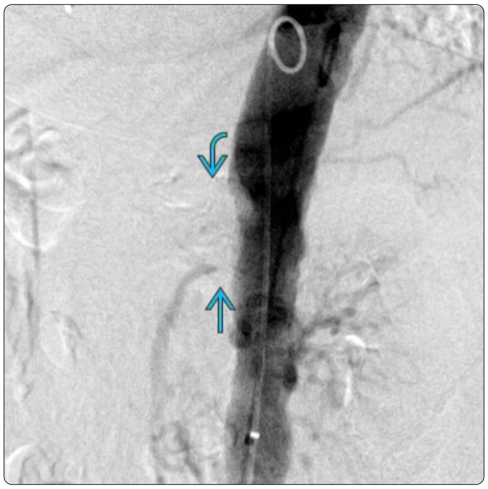
(Left) *The symptoms worsened with conservative management, & thus intervention was considered. The SMA was catheterized, and the venous-phase DSA showed the main trunk of the superior mesenteric vein to be occluded ↪. Venous drainage was via enlarged collaterals ➡.* **(Right)** *Portal-mesenteric access was obtained via a transjugular transhepatic approach, and transcatheter thrombolysis was performed using tPA. DSA afterward showed patency had been restored ↪ to the occluded segment.*

(Left) *A 72-year-old woman presented to the ED with diarrhea and progressive worsening of long-standing abdominal pain. A CECT revealed occlusion of the celiac artery, high-grade SMA stenosis* → *, and significant aortic atherosclerotic calcifications.* **(Right)** *A colonoscopy was performed suggesting areas of colonic ischemia. Following a consultation to Interventional Radiology, a mesenteric angiogram confirmed occlusion of the celiac origin* ↗ *and high-grade stenosis of the SMA origin* →*.*

CMI: Multivessel Disease (CECT)

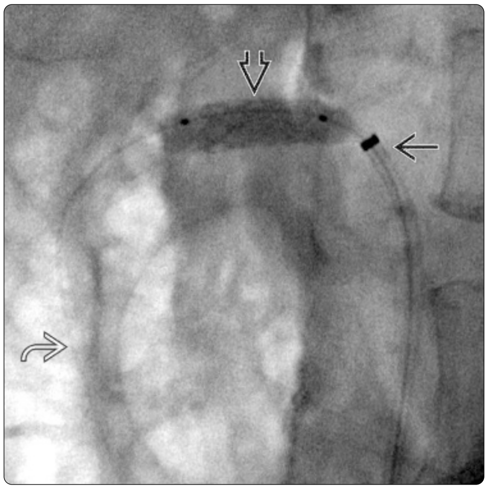


CMI: Multivessel Disease (Lateral Aortic DSA)

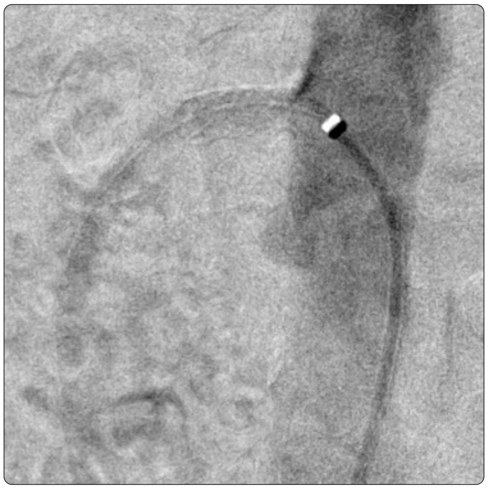


(Left) *The flush catheter was removed over a 0.035" Amplatz wire, and a 7-Fr angled guide sheath* → *was advanced to the SMA origin. A balloon-mounted noncovered stent* ⇒ *was deployed over a stiff 0.14" Grandslam wire* ➔*.* **(Right)** *Contrast injection via the guide sheath confirms patency of the SMA. The stent is well positioned. Antiplatelet therapy was immediately started. The patient's symptoms completely resolved.*

CMI: Multivessel Disease (Stent Placement)

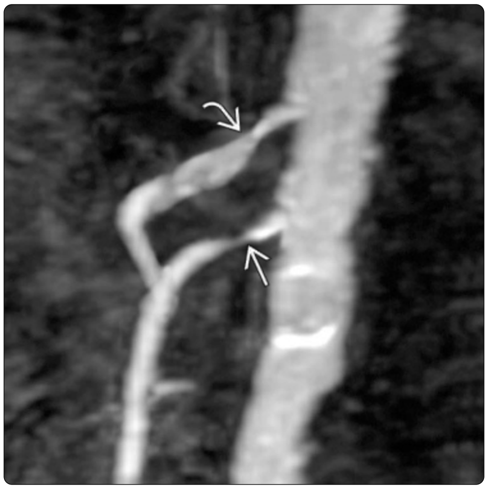


CMI: Multivessel Disease (Final DSA)

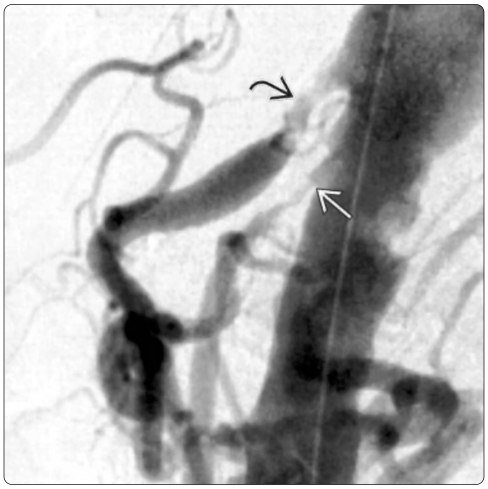


(Left) *A 68-year-old woman with marked weight loss, anorexia, and abdominal pain was suspected of having a malignancy. Instead, a sagittal MRA revealed stenoses of the celiac artery* ➔ *and SMA* ➔*.* **(Right)** *In preparation for treatment of the stenoses with intravascular stent placement, a lateral DSA of the abdominal aorta was obtained. This confirmed the celiac artery* ↗ *and SMA* ➔ *stenoses and demonstrated that the latter was more severe.*

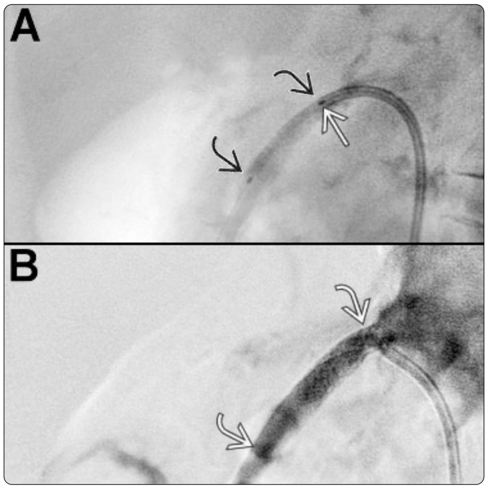
CMI: Multiple Patent Mesenteric Arteries (Initial MRA Evaluation)



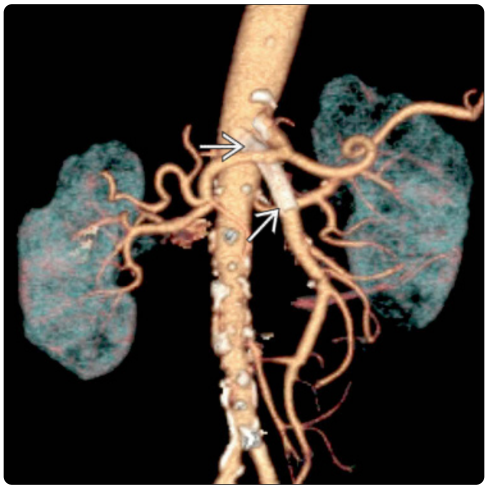
CMI: Multiple Patent Mesenteric Arteries (Lateral Aorta DSA Evaluation)



CMI: Multiple Patent Mesenteric Arteries (Noncovered Stent Placement)

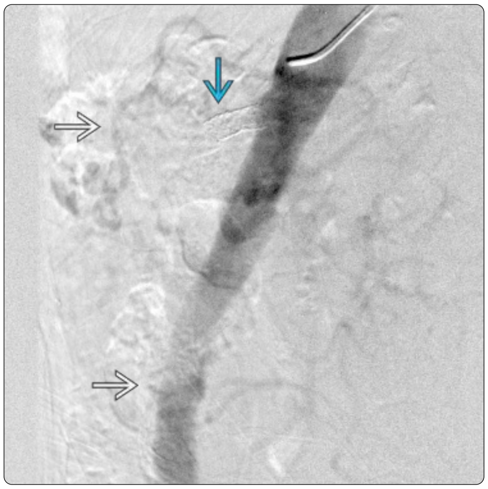


CMI: Multiple Patent Mesenteric Arteries (Follow-Up CTA 3D Reformation)

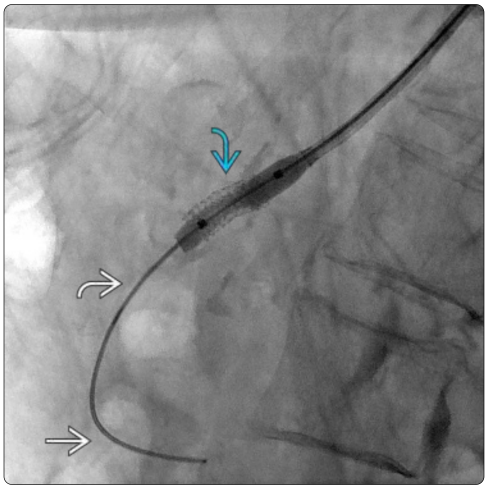


(Left) *(A) With the guiding sheath tip → beyond the SMA origin, a balloon-mounted stent ⇨ was advanced across the stenosis. Contrast injection via the sheath confirmed the stent position before deployment. (B) Poststenting DSA shows a satisfactory stent position ↪, thus eliminating the stenosis.* **(Right)** *A coronal 3D CT reformation of the abdominal aorta and side branches demonstrates the entire distribution of the SMA stent → and shows that the complete length of the stenosis has been treated.*

CMI: In-Stent Occlusion of Common Origin (Brachial Access Lateral Aortogram)

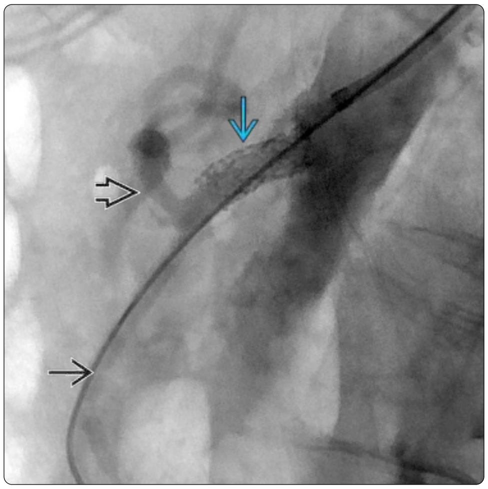


CMI: In-Stent Occlusion of Common Origin (Recanalization of Stent)

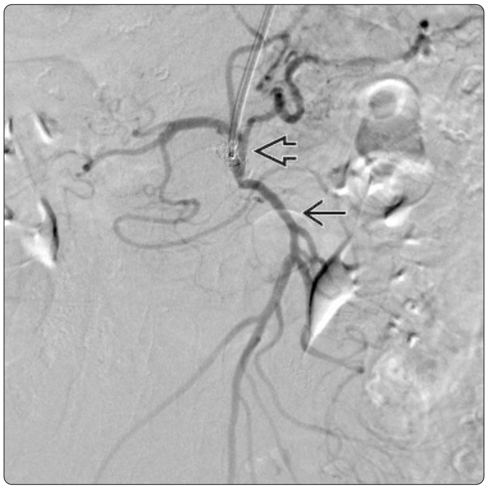


(Left) *A patient presented to the ED with acute-on-chronic abdominal pain. Duplex ultrasound could find no flow within the patient's preexisting mesenteric artery stent. A lateral aortogram (via brachial access) confirmed occlusion of the stent ⇨. An IMA collateral pathway → was noted.* **(Right)** *The stent was traversed with an 0.035" Terumo Advantage wire (hydrophilic tip →, stiff core ↪). Six-mm diameter in-stent PTA ↪ was performed via a 7-Fr guide sheath. Drug-eluting balloons may have improved outcomes in such cases.*

CMI: In-Stent Occlusion of Common Origin (Post-PTA Angiogram)



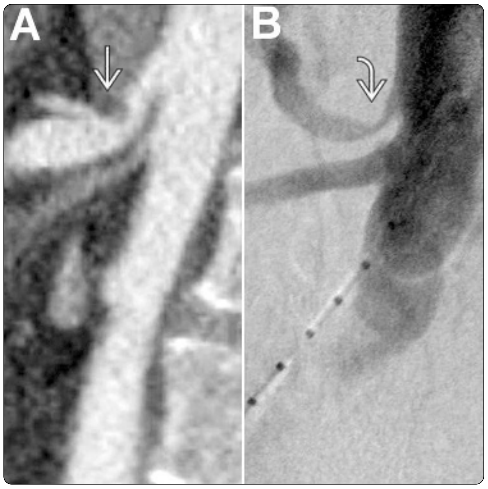
CMI: In-Stent Occlusion of Common Origin (Final Common Origin Anterior DSA)



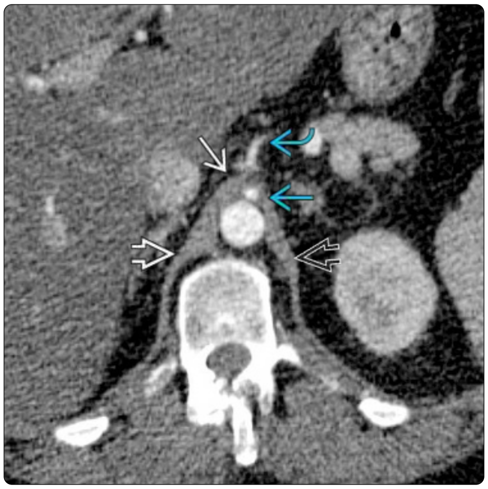
(Left) *Flow is restored into the common origin stent ⇨ and SMA ⇨ and celiac artery ⇨ origins. Residual intimal hyperplasia remains within the stent, which must be closely monitored. Duplex ultrasound or CECT at 1 month and every 6 months thereafter would be reasonable. Antiplatelet therapy should be initiated.* **(Right)** *The celiac ⇨ and SMA ⇨ territories are seen following stent recanalization. Although this was a chronic underlying condition, the large territory involved necessitated acute recanalization.*

(Left) *(A) A sagittal CECT in a woman with weight loss and postprandial abdominal pain shows celiac artery narrowing ➡ beyond its origin. The round density extrinsically narrowing the artery is the median arcuate ligament. (B) DSA shows the "hook" configuration ↪ of the celiac trunk that is characteristic of median arcuate ligament compression.* **(Right)** *The right ⇨ and left ⇨ diaphragmatic crura join to form the median arcuate ligament ➡, a fibrous arch that compresses the celiac artery (seen proximally → and distally ↪).*

CMI: Median Arcuate Ligament Syndrome

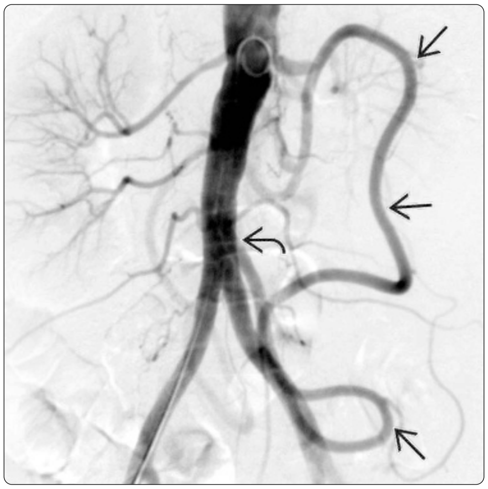


CMI: Median Arcuate Ligament Syndrome

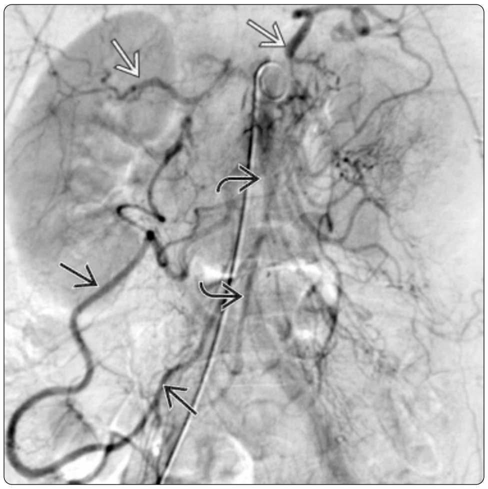


(Left) *DSA in a patient with symptoms suggesting chronic mesenteric ischemia shows an abnormally large artery → arising from the expected location of the IMA origin ↪. It fills in retrograde fashion & has a meandering course that is typical of the arc of Riolan, an inconstant arcade that connects the IMA & SMA.* **(Right)** *Delayed DSA shows the continuation of the arc of Riolan →. It reconstitutes the SMA ↪ & branches ➡ of the celiac artery, both proximally occluded due to Takayasu arteritis.*

CMI: Vasculitis (Early Aortogram)

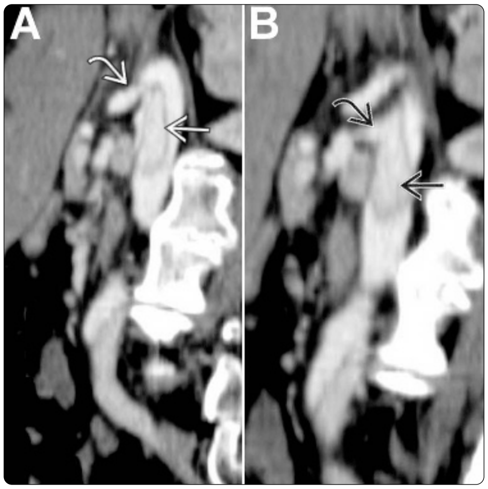


CMI: Vasculitis (Late Aortogram)

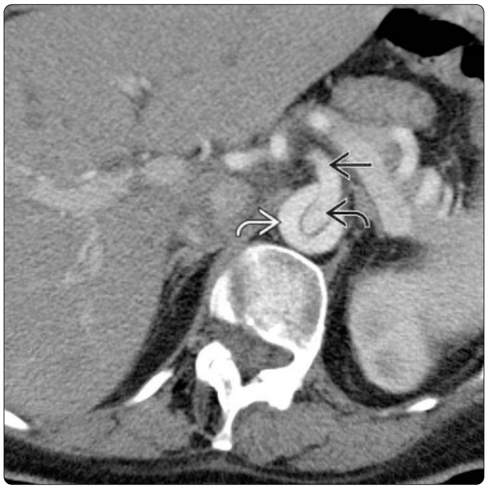


(Left) *A Marfan syndrome patient with a known thoracoabdominal aortic dissection had recurrent postprandial abdominal pain, anorexia, and weight loss. (A) An aortic dissection flap ➡ is seen with the true lumen supplying the celiac artery ↪. (B) The SMA is patent ↪ but arises from the false lumen →.* **(Right)** *The true lumen ↪ of the aortic dissection is around the SMA →, which is supplied by the false lumen ↪. A well-defined intimal flap is present. Poor perfusion from the false lumen caused chronic mesenteric ischemia.*

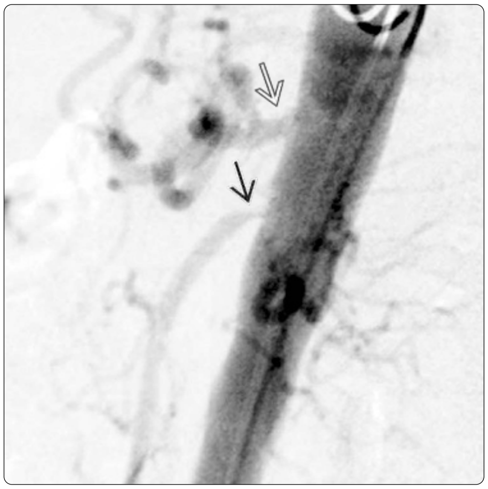
CMI: Thoracoabdominal Aortic Dissection (Sagittal CECT)



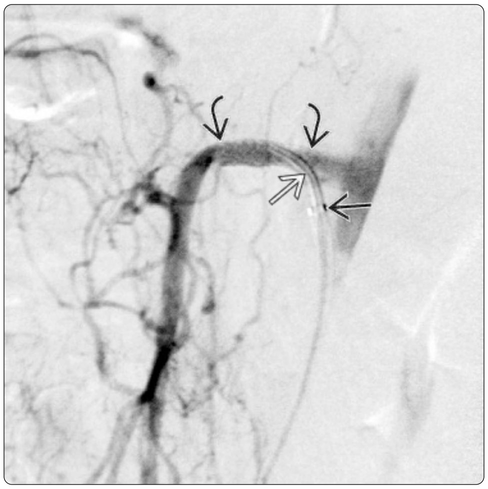
CMI: Thoracoabdominal Aortic Dissection (Axial CECT)



Complication: Embolus After Stenting (Initial Lateral Aorta DSA)

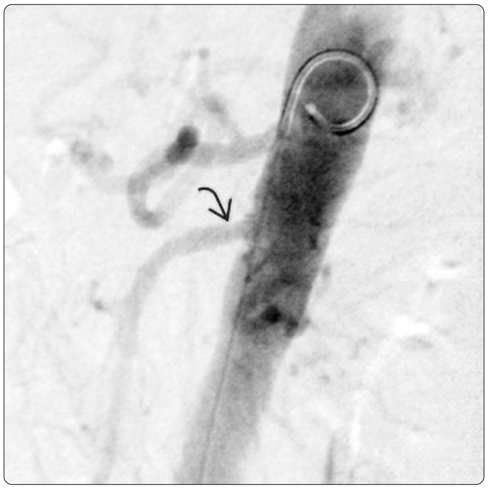


Complication: Embolus After Stenting (Noncovered Stent Placement)

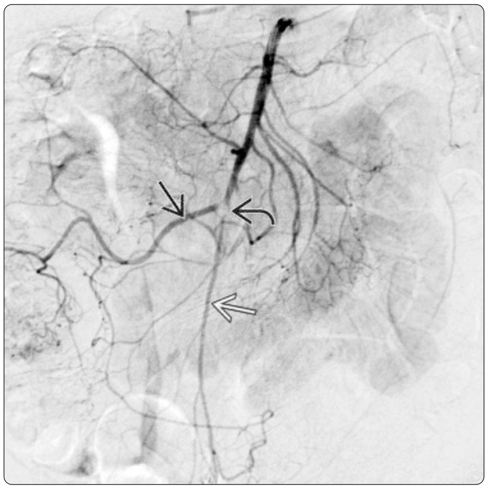


(Left) *Lateral aorta DSA in a patient with anorexia, aversion to food, and weight loss shows a severe stenosis of the SMA origin ⇨ and a normal caliber to the celiac artery ➡. The IMA origin was also stenotic. Based on the patient's symptoms and the DSA findings, treatment of the SMA stenosis was planned.* **(Right)** *DSA via a guiding sheath ⇨ and coaxial 5-Fr Cobra catheter ➡ after superior mesenteric artery stenting shows a stent ↪ in place and no obvious residual stenosis.*

Complication: Embolus After Stenting (Post Stent Lateral Aorta DSA)

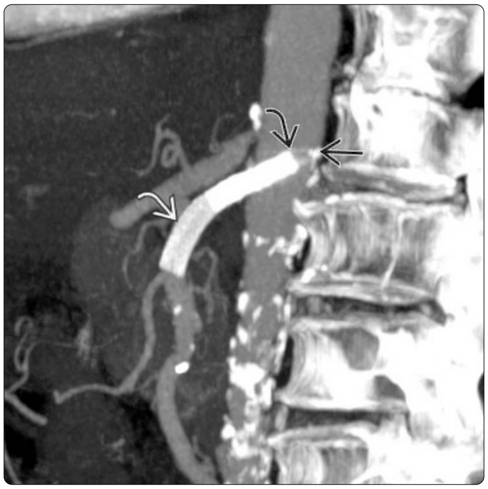


Complication: Embolus After Stenting (SMA DSA)

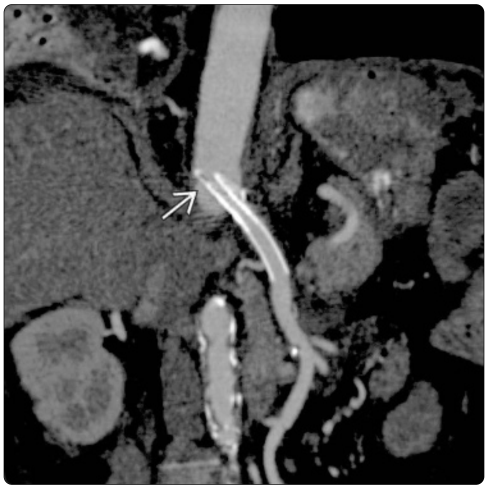


(Left) *Lateral aorta DSA after stent placement better demonstrates the position of the stent ↪ in the SMA and its relationship to the aorta. The DSA also reconfirms that the proximal SMA is widely patent.* **(Right)** *Anteroposterior DSA after stent placement shows a small nonocclusive filling defect ↪ in the distal SMA at the division into the right colic ⇨ and ileocolic ➡ arteries. This represents a small distal embolus that occurred during stent placement. The patient was asymptomatic and was thus systemically heparinized with no adverse sequelae.*

Complication: Malpositioned Noncovered Stent (3D CTA Reformation)



Complication: Malpositioned Noncovered Stent (Curved CT Reconstruction)



(Left) *During noncovered stent placement to treat a lengthy stenosis of the proximal SMA and its origin, the proximal end of the stent ↪ was malpositioned, extending almost to the posterior wall ⇨ of the aorta. A 2nd stent ➥ was extended further into the SMA to ensure complete stenosis coverage.* **(Right)** *Again, the suboptimal position of the proximal end ➡ of the 1st stent is seen. This image, however, confirms stent patency.*

KEY FACTS

TERMINOLOGY

- **True aneurysm**: Contains all 3 layers of arterial wall
- **Pseudoaneurysm**: Contains hemorrhage via arterial wall defect; does not contain all 3 arterial wall layers
- **Fibromuscular dysplasia**: Noninflammatory arteriopathy; typically produces stenoses
  - Abnormal cellular growth in walls of medium to large arteries; causes fibrous thickening
- **Segmental arterial mediolysis**: Nonatherosclerotic, noninflammatory arteriopathy
  - Characterized by dissections and aneurysms

PREPROCEDURE

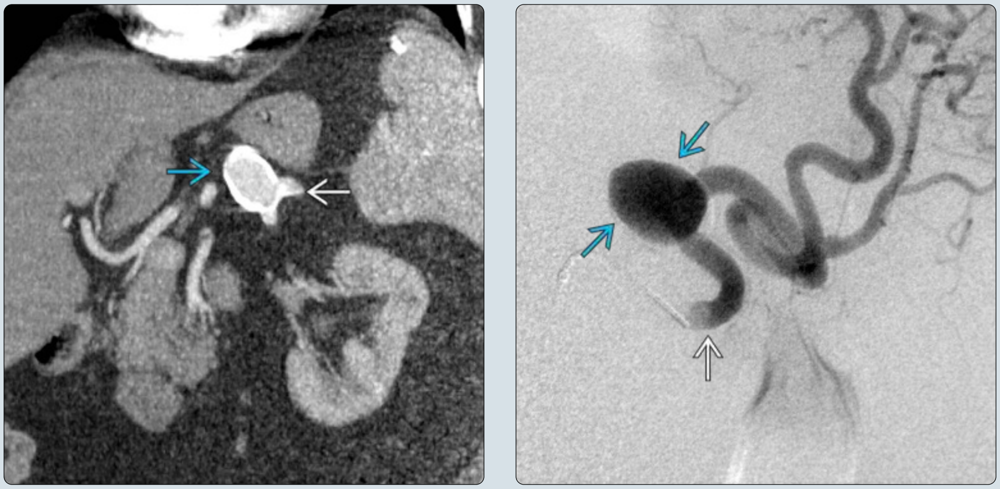
- **Indications for intervention**
  - All pseudoaneurysms require treatment
  - True aneurysms ≥ 2 cm in diameter require treatment
  - Active hemorrhage from visceral arterial source
  - Symptomatic visceral artery stenoses/occlusions

PROCEDURE

- Various intervention options for treating pseudoaneurysms/aneurysms & active bleeding
  - Embolization proximal & distal to lesion
  - Direct transcatheter embolization of aneurysm/pseudoaneurysm sac with coils/liquids
  - Stent-assisted coil embolization or covered stent placement; useful for treating wide-necked lesions
- Goal is to achieve persistent thrombosis
- Stent symptomatic stenoses/occlusions if warranted

OUTCOMES

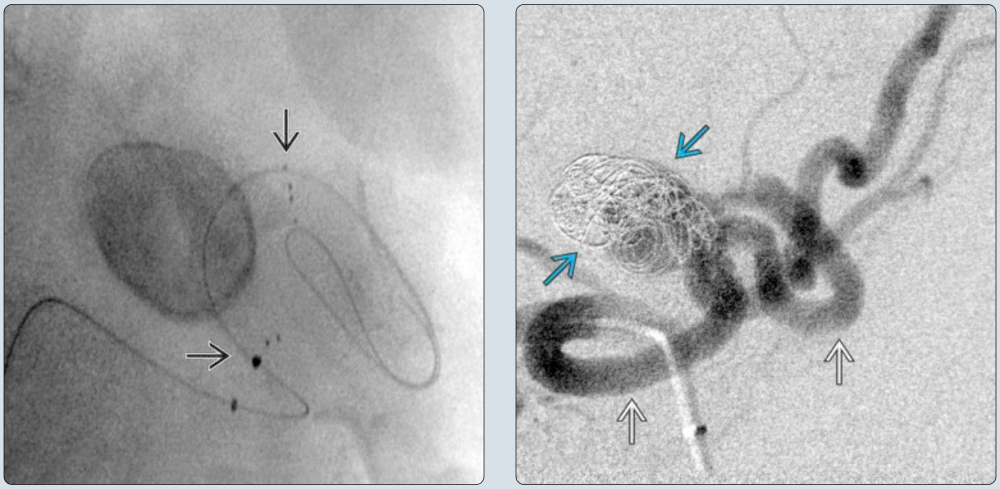
- 79-98% technical success rate in visceral artery aneurysm/pseudoaneurysm intervention
- 4% require future reintervention; follow-up imaging is essential



Splenic Artery Aneurysm (Coronal CTA)

Splenic Artery Aneurysm (Diagnostic DSA)

(Left) *A large, wide-neck calcified aneurysm ⇨ is seen arising from the splenic artery ➡. Due to its size and risk of impending rupture, therapy is indicated.* **(Right)** *With a catheter located in the proximal splenic artery ➡, DSA demonstrates the large aneurysm ⇨ arising off the mid splenic artery, corresponding to findings from the CTA.*



Splenic Artery Aneurysm: Stent-Assisted Coiling (Placement of Stent)

Splenic Artery Aneurysm: Stent-Assisted Coiling (Placement of Coils)

(Left) *A noncovered stent ⇨ has been placed within the splenic artery (across the neck of the aneurysm) to provide protection during coil embolization of splenic artery aneurysm. Noncovered stents typically track through tortuous vessels easier than would covered stents.* **(Right)** *A microcatheter was advanced through the stent interstices into the aneurysm sac, and coils were deployed. DSA shows partial occlusion of the aneurysm ⇨ and patency of the splenic artery ➡. Delivery of additional coils may be necessary.*

TERMINOLOGY

Definitions

- **Visceral artery aneurysms**: Relatively infrequent
  - Incidence of 0.1-2.0% in general population
    - Reported rupture rates of 20-70%
      - 50% present with rupture
      - 8.5-75.0% mortality rate (location dependent)
  - Various etiologies
    - Atherosclerosis (most common)
    - Infection (mycotic)
    - Trauma
    - Genetic
      - Marfan syndrome
      - Klippel-Trenaunay-Weber syndrome
      - Ehlers-Danlos syndrome
      - Behçet syndrome
    - Vasculitis
    - Iatrogenic intervention
  - Visceral artery aneurysm distribution
    - Splenic artery: 60-80%
    - Hepatic artery: 20%
    - Superior mesenteric artery (SMA): 5%
    - Gastroduodenal/gastroepiploic artery: 4%
  - **True aneurysm**: Contains all 3 layers of arterial wall
    - Degenerative process involving arterial wall
    - Rupture risk increases when size ≥ 2 cm
  - **Pseudoaneurysm (false aneurysm)**: Arterial wall disruption with focal contained hemorrhage
    - Does not contain all 3 layers of arterial wall
    - Typically associated perivascular inflammation
      - Etiologies include trauma, infection, vasculitis
    - High risk of rupture
      - Usually require treatment, regardless of size
    - Increasing incidence from iatrogenic injury
      - Endoscopic/percutaneous biliary interventions
      - Laparoscopic interventions
      - Transarterial chemo-/radioembolization
      - Transplantation related
- **Fibromuscular dysplasia (FMD)**: Noninflammatory arteriopathy typified by abnormal cellular growth in walls of medium to large arteries
- **Segmental arterial mediolysis (SAM)**: Nonatherosclerotic, noninflammatory arteriopathy
  - Histology shows vacuolar degeneration of smooth muscle in outer media of arterial wall
  - Clinical symptoms include acute abdominal pain and hemorrhage in late middle-aged & elderly patients
  - Responds poorly to angioplasty & other interventions

PREPROCEDURE

Indications

- Most visceral artery interventions involve treating visceral aneurysms/hemorrhage/stenoses/occlusions
  - All pseudoaneurysms require treatment
    - Endovascular treatment preferred over surgery
  - Indications for true visceral aneurysm intervention
    - Aneurysms ≥ 2 cm in diameter or enlarging
    - Aneurysms in women of childbearing age due to increased rupture risk in pregnancy
    - Aneurysms in liver transplantation patients; occur in either pretransplant or posttransplant patients
      - Surgical treatment for pretransplant aneurysms
      - Most posttransplant aneurysms are actually pseudoaneurysms; managed endovascularly
    - Symptomatic aneurysms
      - Distal embolization/hemorrhage/rupture
  - Active hemorrhage from visceral arterial source
    - May be iatrogenic/inflammatory/traumatic
  - Symptomatic visceral artery stenoses/occlusions
    - Celiac/mesenteric artery stenosis/occlusion causing mesenteric ischemia (acute or chronic)
    - Celiac/hepatic artery stenosis/occlusion compromising allograft after liver transplantation
  - Symptomatic (flow-limiting) visceral artery dissections

Contraindications

- Uncorrectable coagulopathy
- Anaphylaxis to iodinated contrast medium
- Mycotic visceral artery aneurysm (treated with surgical resection/bypass)

Preprocedure Imaging

- CTA
  - Excellent delineation of arterial anatomy & pathology
  - High sensitivity in detecting visceral artery aneurysms/hemorrhage/stenoses/occlusions
  - Can demonstrate SAM and FMD
    - FMD classically has alternating aneurysms and stenoses; leads to string of beads appearance
    - SAM has segmental or skip pattern
    - Dissecting aneurysms more frequent in SAM
    - Different arterial distribution in SAM
      - Celiac artery/branches: 60%
      - SMA: 17%
      - Renal arteries: 14%
      - Inferior mesenteric artery: 9%
- MRA
  - Excellent delineation of arterial anatomy & pathology
  - High sensitivity in detecting visceral artery aneurysms, hemorrhage, & stenoses/occlusions
- DSA
  - Gold standard for detecting arterial pathology
  - Imaging guidance for transcatheter intervention

Getting Started

- Things to check
  - Clinical history and physical examination
    - Appropriate procedure indications
    - Current medications: Anticoagulants, antiplatelet agents
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - CBC
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ratio ≤ 1.5

        - ☐ Normal prothrombin time, partial thromboplastin time
    - ○ Limit oral intake: NPO for 8 hours prior to procedure if moderate sedation/general anesthesia planned
    - ○ Informed procedural & sedation consent obtained
- Medications
    - ○ Agents for moderate sedation
        - – Fentanyl
        - – Midazolam
    - ○ Heparin
    - ○ Vasodilator (e.g., nitroglycerin) for preventing/treating catheter-induced vasospasm
    - ○ 1-2% lidocaine local anesthesia
- Equipment list
    - ○ Access sheath
        - – 5- to 8-Fr vascular access sheath (size depends on catheters/delivery systems)
    - ○ Catheters
        - – Diagnostic catheter
            - ☐ Flush catheter [e.g., pigtail, OmniFlush (AngioDynamics; Queensbury, NY)]
            - ☐ Selective catheter (e.g., Cobra, Simmons)
        - – Coaxial 2.6- to 3.0-Fr microcatheter
        - – Angioplasty (PTA) balloon catheter
    - ○ Guidewires
        - – Initial "starting" 0.035" guidewire
        - – Angled or straight-tipped hydrophilic guidewire: Beneficial for selective catheterization
        - – Stiff guidewire (e.g., Amplatz, Rosen): Can provide stability when advancing/placing devices
        - – 0.014-0.018" microwire
    - ○ Stents
        - – Noncovered self-expanding/balloon-mounted
            - ☐ Used for treating stenoses or stent-assisted coiling
        - – Covered self-expanding/balloon mounted
            - ☐ Used for treating stenoses or arterial exclusion
    - ○ Embolic agent(s)
        - – Coils
            - ☐ Detachable or "pushable" 0.035" or 0.018" embolization coils
        - – Liquids
            - ☐ n-butyl cyanoacrylate (n-BCA) Trufill (Cordis; Bridgewater, NJ)
            - ☐ Onyx (ev3 Neurovascular; Irvine, CA)
            - ☐ Thrombin: Activates coagulation cascade
        - – Gelfoam (Upjohn; Kalamazoo, MI)
            - ☐ Temporary embolic agent available in sheet form; can cut into pledgets/create slurry
        - – Particles
            - ☐ Various sizes, composition
            - ☐ Rarely, if ever, indicated for treatment of aneurysms/pseudoaneurysms
            - ☐ May be necessary for treating parenchymal hemorrhage following solid organ trauma
        - – Plug occluding device
            - ☐ Amplatzer plug (St. Jude Medical; St. Paul, MN)

PROCEDURE

Patient Position/Location

- Best procedure approach
    - ○ Determined by location of target for embolization
        - – Common femoral artery access typically used
        - – Direct percutaneous puncture of target lesion if lesion inaccessible to catheterization
- Challenges to obtaining diagnostic quality DSA images
    - ○ Patient movement
    - ○ Respiratory movement (critical to have patient hold breath)
    - ○ Movement from bowel peristalsis
        - – Can administer IV glucagon or IV smooth muscle relaxant: Hyoscine butylbromide (Buscopan)
    - ○ Review of unsubtracted images helpful in differentiating misregistration artifact and pathology

Procedure Steps

- **General**
    - ○ Sterilely prepare & drape intended access site
    - ○ Administer 1-2% lidocaine local anesthesia
    - ○ Obtain arterial access
    - ○ Introduce flush catheter if aortogram needed
        - – Inject contrast; obtain DSA images, and localize target artery
    - ○ Selectively place catheter in target vessel
        - – Inject contrast; obtain DSA images
    - ○ Consider guiding catheter/sheath or coaxial microcatheter use as needed for intervention
        - – Proceed with appropriate intervention
- **Embolization** of visceral pseudoaneurysms/aneurysms & bleeding: Technique influenced by location & morphology of target lesion
    - ○ **Coil embolization technique (general)**
        - – Place sheath, introduce diagnostic catheter
            - ☐ Position selective catheter in target vessel
        - – Obtain diagnostic DSA
            - ☐ Analyze images, plan embolization
        - – Embolization may require coil placement proximal and distal to aneurysm/bleeding site
            - ☐ Distal coils prevent retrograde perfusion of lesion
            - ☐ Increase risk of end-organ infarction
        - – Embolization may or may not include coiling of sac when treating aneurysm/pseudoaneurysm
            - ☐ May not be possible with wide-necked lesions
            - ☐ May be problematic in pseudoaneurysms; often have thin walls, which can rupture
        - – May use either 0.035" or 0.014-0.018" system
            - ☐ Introduce coaxial microwire & microcatheter if using microcoils
            - ☐ Position microcatheter tip for embolization
        - – Proceed with coil embolization
            - ☐ May monitor using roadmap fluoroscopy
        - – Use coils slightly larger than target diameter
            - ☐ For aneurysms, frame with 3D-type coil first; follow with filling coils and finishing coils
        - – May use detachable coils for precise placement
            - ☐ Can retrieve & reposition coil until detached, for limited amount of time

    - May follow with pushable coils
  - Use intermittent contrast injection during coiling to verify coil positions & assess embolization
  - Obtain postcoiling DSA to document final result
- **Stent-assisted coiling technique**
  - Useful for wide-necked aneurysms
    - Allows coiling of aneurysm sac without coil protrusion into adjacent parent vessel
  - Place guidewire & catheter beyond aneurysm
  - Measure target vessel diameter & lesion length to determine appropriate stent size
  - Deploy stent across aneurysm neck
  - Place microcatheter through stent interstices into aneurysm; inject contrast to confirm position
    - Introduce coils into aneurysm via microcatheter
    - Coils should fill lumen of aneurysm outside of stent lumen, occluding aneurysm
    - Lumen of stent & parent vessel remain patent
  - Obtain postcoiling DSA to document final result
- **Balloon-assisted coiling technique**
  - Also useful for wide-necked aneurysms
    - Gives temporary balloon support while coiling; prevents coil migration & nontarget embolization
  - Use 6- to 8-Fr guiding catheter
    - Systemically heparinize patient
  - Via guiding catheter, coaxially introduce compliant balloon; place balloon across aneurysm neck (do not inflate)
  - Via guiding catheter, place coaxial microcatheter into aneurysm sac; now inflate balloon across neck
  - Place framing coils with balloon inflated
    - Deflate balloon before detaching coil to see conformation, relationship with parent vessel
    - Balloon only transiently inflated (~ 2 min)
  - After framing coils, place filling/finishing coils
    - Can safely insert latter without inflating balloon
  - Inflate balloon when removing microcatheter to prevent coil dislodgement
- **Plug occluding device technique**
  - Selectively catheterize target artery
    - Inject contrast; obtain DSA images
  - Determine appropriate size & configuration of plug occluding device for embolization; based on vessel type, blood flow, available "landing zone"
    - Amplatzer vascular plug: Short "landing zone," single-layer mesh, single-lobe design
    - Amplatzer vascular plug II: Variable "landing zone," multilayered mesh lobes produce larger surface area
    - Amplatzer vascular plug III: For high-flow target embolization, multiple meshes & extended rims help hold plug in place
    - Amplatzer vascular plug IV: Low-profile plug; delivered via 0.038" diagnostic catheter
  - Should use plug occluder sized 30-50% larger than vessel diameter at intended occlusion site
  - Must be able to advance delivery sheath (or 0.038" catheter) into target vessel for plug placement (only low-profile device can be delivered via catheter)
  - Device is self-expanding
    - Retract sheath/catheter for delivery
    - Device is attached to delivery wire; can recapture & reposition device until detached
  - Obtain DSA to confirm satisfactory position of plug & occlusion of target
  - Detach by counterclockwise rotation of delivery wire
  - Obtain final image
- **Liquid embolic agent technique (general)**
  - Liquids provide excellent penetration & occlusion
    - Delivery sometimes difficult to control
    - Potential for nontarget embolization, especially if high-flow hemodynamics
    - Inject selectively into vessels supplying target; may otherwise injure adjacent normal tissue
- **n-BCA liquid embolization technique**
  - Selectively place microcatheter into target
    - Inject contrast; obtain DSA images
  - Draw desired volume of Ethiodol into syringe
    - Mix n-BCA with Ethiodol; higher n-BCA concentration solidifies faster
    - Proportion mixture concentration according to flow characteristics & operator experience
  - Tantalum powder increases radiopacity of n-BCA when mixture > 70% n-BCA
  - Flush microcatheter with D_5W-filled 3-mL syringe
  - Remove slack from microcatheter
  - Fluoroscopically monitor n-BCA injection
    - Use blank roadmap mask while injecting; allows better visualization of embolic agent
  - After injection, aspirate syringe & quickly withdraw microcatheter
    - Avoids catheter tip being glued into place
- **Onyx embolization technique**
  - Onyx: Ethylene vinyl alcohol copolymer (EVOH), dissolved in dimethyl sulfoxide (DMSO) with suspended micronized tantalum powder
    - Use Onyx 34 for high-flow lesions; precipitates on contact with blood as DMSO dissipates
    - Onyx forms cast that seals off lesion
  - Selectively place microcatheter into target
    - Inject contrast; obtain DSA images
  - Flush microcatheter with D_5W-filled 3-mL syringe
  - Use compatible syringe to draw 1 mL DMSO
    - Attach DMSO syringe to microcatheter hub
    - Fill dead space of microcatheter (usually 0.2–0.3 mL) with DMSO over 1–2 min
  - Connect catheter hub and Onyx syringe
    - Keep syringe vertical with plunger down
  - Slowly inject Onyx (~ 0.15 mL/min)
    - Continually monitor injection fluoroscopically
    - Use blank roadmap mask during injection
  - If not going to desired location, pause injection for 15-30 s, then resume injecting
    - Avoid reflux of Onyx into normal arteries
    - Avoid occluding normal venous drainage
  - Do not pause injection for more than 2 min
    - Onyx may solidify and clog microcatheter
  - To remove microcatheter, aspirate syringe and slowly pull back microcatheter
    - Should not "glue" into place
- **Percutaneous thrombin injection**

    - Consider if lesion (e.g., pseudoaneurysm/aneurysm) inaccessible for transcatheter therapy
    - Place small-bore needle (e.g., 22 g) into aneurysm/pseudoaneurysm lumen
      - May use CT, US, or fluoroscopic guidance
    - Inject thrombin (500-1,000 U/mL) slowly
    - Use increments of 0.1 mL up to total volume of 1-2 mL
- **Stenting of visceral artery lesions**
  - Consider noncovered stent for treatment of symptomatic visceral artery dissections, stenoses, & occlusions
    - Most frequent indication: Mesenteric ischemia
  - Consider covered stent for exclusion of visceral artery wall defect (e.g., pseudoaneurysm/aneurysm or hemorrhage)
    - Fabric-covered stent excludes diseased arterial segment while maintaining blood flow distally
    - May be technically challenging
      - Larger delivery systems usually needed for covered stents (other than balloon mounted)
      - May be difficult to reach target lesion with covered stent if tortuous feeding artery
      - Covered stent may occlude branch vessels
- **Special considerations**
  - **Hepatic or splenic trauma with ongoing parenchymal hemorrhage**
    - Initial treatment should be fluid resuscitation
      - Hemodynamically unstable patients need urgent laparotomy
    - Conservative management with careful clinical & imaging monitoring may be appropriate
      - Delayed, recurrent hemorrhage may occur
    - Embolization indicated for refractory hemorrhage
      - May use Gelfoam, particles, &/or coils
  - **SAM interventions**
    - Base decision to intervene on clinical findings
      - Acute phase of SAM can have 50% mortality rate due to intraabdominal hemorrhage
      - Endovascular intervention may include embolization with coils or n-BCA
    - Avoid angioplasty due to compromised media
      - If angioplasty performed, do not dilate beyond nominal adventitial diameter
  - **Pancreaticoduodenal artery aneurysms**
    - Associated with increased collateral flow in presence of severe celiac/SMA stenosis/occlusion
      - Rupture may be life threatening
      - Selective embolization may be necessary
  - **Splenic artery aneurysms**
    - Catheter access to aneurysm may be difficult
      - Typically very tortuous artery
    - May be unable to preserve splenic artery patency
      - If unable to access aneurysm, treatment may require splenic artery embolization
    - Proximal embolization increases pancreatitis risk
      - Pancreatic arteries arise proximally
  - **Splenic artery embolization for hypersplenism**
    - Alternative to splenectomy
      - Embolization performed distally
      - Gelfoam or particles typically used
    - Aim of reducing splenic volume by 60-80%
      - Achieves reduction in splenic size; may require repeat embolization sessions
      - Preserves some functioning splenic tissue
    - Use periprocedural broad-spectrum antibiotics
    - Avoid complete splenic infarction
      - Can result in splenic abscess

Alternative Procedures/Therapies

- Surgical
  - Surgical ligation, bypass of lesion
  - Urgent laparotomy in posttraumatic bleeding
  - Surgical resection of SAM may be 1st-line treatment

POST PROCEDURE

Things to Do

- Close clinical monitoring after embolization; imaging follow-up as clinically indicated
  - Exclude revascularization of lesion

OUTCOMES

Complications

- Most feared complication(s)
  - Complete/partial end-organ infarction
    - Some degree of infarction in up to 20% of interventions often with minimal clinical consequences
    - Embolization relies on adequate collateral supply to prevent end-organ infarction
- Immediate/periprocedural complication(s)
  - Access site complications
    - Hematoma, pseudoaneurysm, iatrogenic arteriovenous fistula
  - Arterial dissection
  - Intraprocedural aneurysm/pseudoaneurysm rupture
  - Nontarget embolization
- Delayed complication(s)
  - Pancreatitis with proximal splenic artery embolization

Expected Outcomes

- 79-98% technical success rate in visceral artery aneurysm/pseudoaneurysm intervention
  - 99% visceral preservation
  - 4% require future reintervention; follow-up imaging is essential
  - 4% major complications (Society of Interventional Radiology criteria)
- 87-95% technical success rate in controlling posttraumatic solid organ hemorrhage

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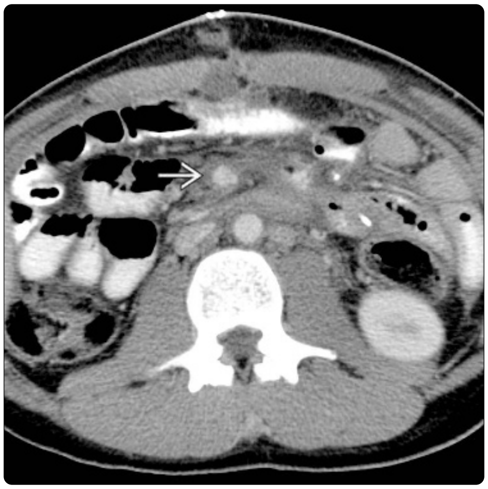
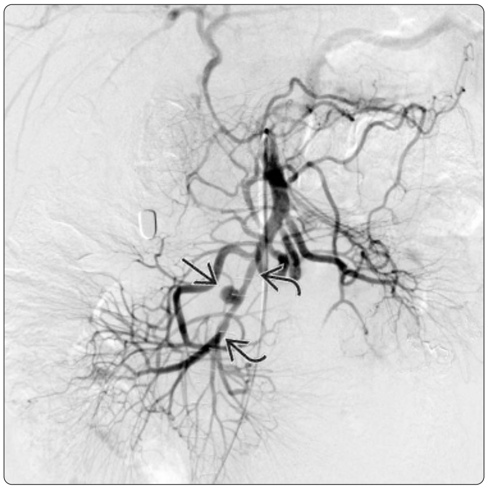
Traumatic SMA Pseudoaneurysm (Initial CECT Evaluation)

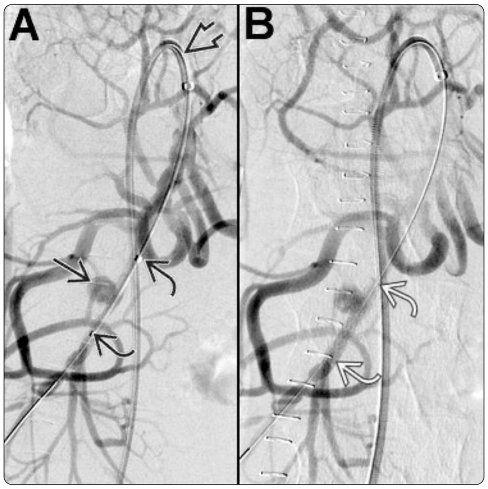


Traumatic SMA Pseudoaneurysm (Initial DSA of SMA)

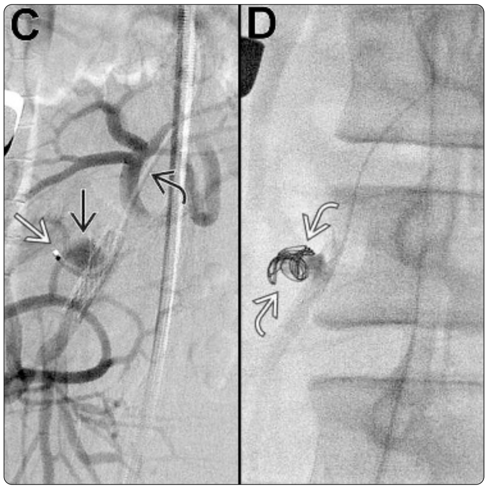


(Left) *A patient sustained an abdominal gunshot wound 1 week earlier, requiring a partial small bowel resection. An axial CECT shows an arterially enhancing mass* ➡ *arising from the superior mesenteric artery (SMA), consistent with a pseudoaneurysm.* **(Right)** *DSA of the SMA shows an eccentric rounded vascular mass* → *arising from the ileocolic segment* ↪ *of the SMA, consistent with a pseudoaneurysm. All pseudoaneurysms require treatment due to the high risk of rupture.*

Traumatic SMA Pseudoaneurysm: Stent-Assisted Coil Embolization (DSA of Stent)

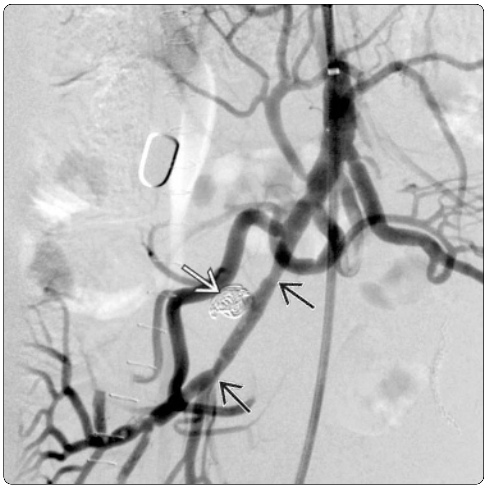


Traumatic SMA Pseudoaneurysm: Stent-Assisted Coil Embolization (Coil Delivery)

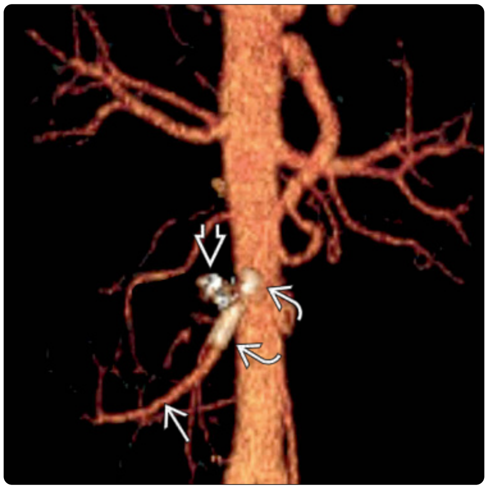


(Left) *(A) A guiding sheath* ⇨ *was placed in the SMA, and a microcatheter was advanced across the lesion. A noncovered stent* ↪ *was positioned across the pseudoaneurysm neck* →*. (B) The stent* ➥ *was deployed, and a repeat DSA was obtained.* **(Right)** *(C) The microcatheter* ↪ *was reintroduced, and the tip* ➡ *was advanced into the pseudoaneurysm sac* → *through the interstices of the noncovered stent. (D) Microcoils* ➥ *were then introduced into the pseudoaneurysm sac.*

Traumatic SMA Pseudoaneurysm: Post Embolization (DSA of SMA)

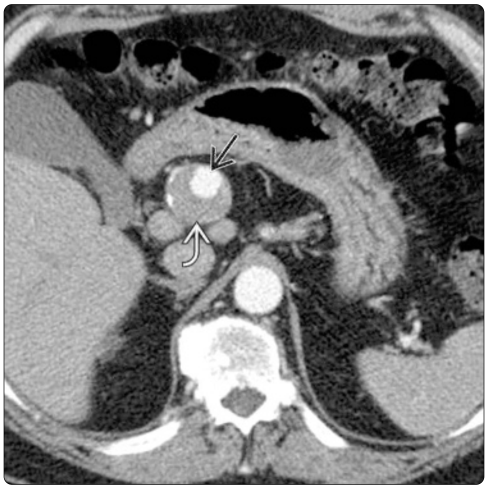


Traumatic SMA Pseudoaneurysm: Post Embolization (3D CTA)

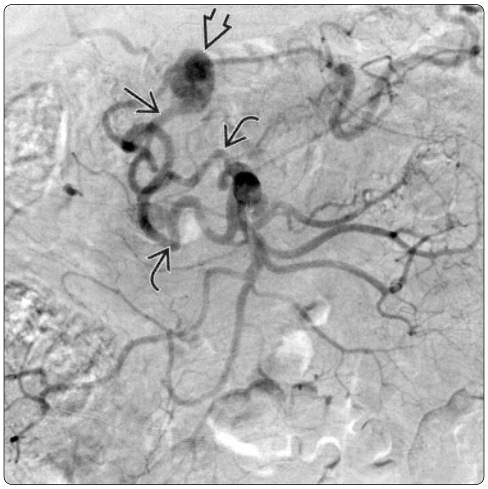


(Left) *After microcoil* ➡ *embolization, the microcatheter was removed, and DSA images were obtained, confirming occlusion of the pseudoaneurysm and preserved patency of the ileocolic artery* → *and distal branches. Stent-assisted coiling is useful for treating wide-necked aneurysms or pseudoaneurysms while preserving distal arterial perfusion.* **(Right)** *Follow-up coronal CECT 3D reformation 1 month later shows patent arteries* ➡ *distal to the stent* ➥ *and coils* ⮕*, with no filling of the pseudoaneurysm.*

(Left) *A 3-cm hepatic artery aneurysm is present, with an eccentric patent lumen → and laminar thrombus ➥ within the aneurysm sac. Aneurysms ≥ 2 cm in diameter should be treated, given the risk of rupture.* **(Right)** *Because of the difficulty in catheterizing the celiac artery, an SMA DSA was performed, revealing marked enlargement of the pancreaticoduodenal ↪ arteries (PDA) and gastroduodenal → artery (GDA). Also demonstrated is the large hepatic artery aneurysm ⇨.*

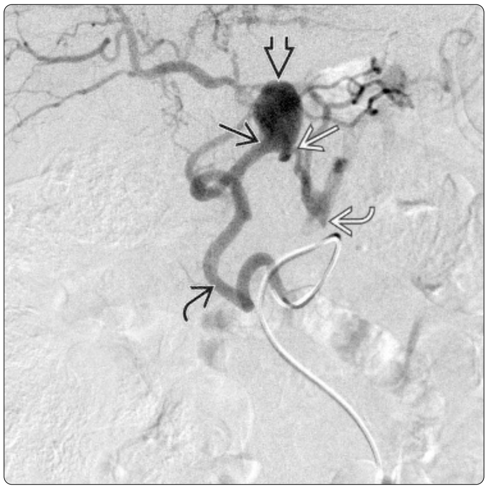


Hepatic Artery Aneurysm (Initial CECT Evaluation)

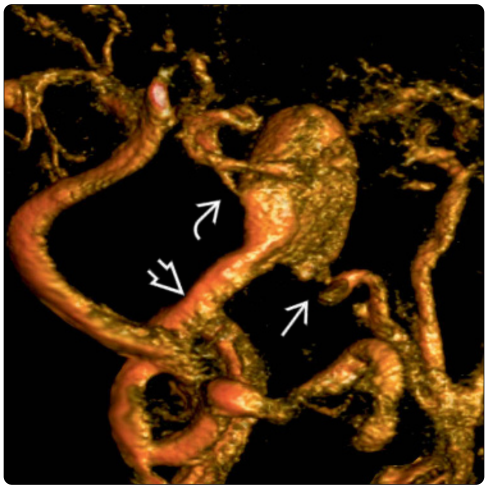


Hepatic Artery Aneurysm (SMA DSA)

(Left) *DSA via a catheter in the inferior PDA ↪ shows that the aneurysm ⇨ arises at the origin of the GDA → from the common hepatic artery ➡. It also shows a severely stenotic celiac artery origin ➥.* **(Right)** *DynaCT angiography was obtained to better evaluate the complex anatomy of the aneurysm. This shows that there are inflow ➡ and outflow ➥ stenoses of the common and proper hepatic arteries relative to the aneurysm, with the dominant blood supply via the GDA ➯.*

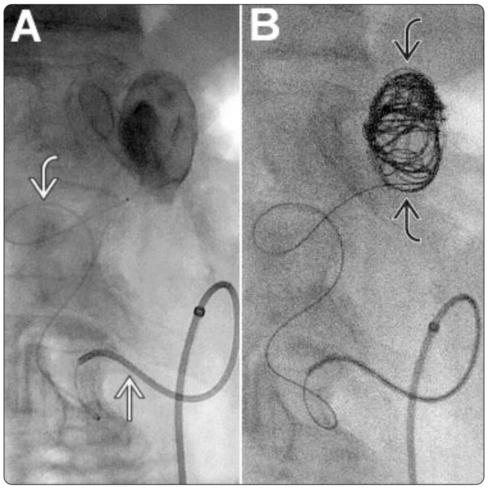


Hepatic Artery Aneurysm (DSA via GDA)

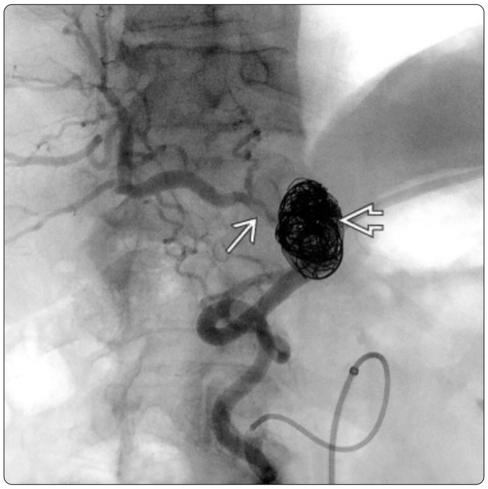


Hepatic Artery Aneurysm (DynaCT Angiography)

(Left) *(A) Via a 5-Fr catheter ➡ in the proximal inferior PDA, a coaxial microcatheter ➥ was placed in the aneurysm, and (B) microcoils ↪ were used for embolization.* **(Right)** *An unsubtracted DSA obtained immediately after coil embolization shows contrast in the proper hepatic artery ➡ beyond the coiled aneurysm ➯, indicating persistent flow thorough the aneurysm. Later, DSA showed sac thrombosis and no hepatic artery flow. There is little risk of hepatic infarction, but bile duct ischemia is a concern.*

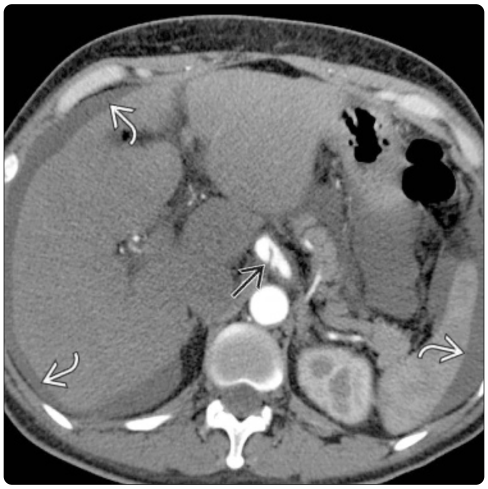


Hepatic Artery Aneurysm: Embolization via Microcatheter

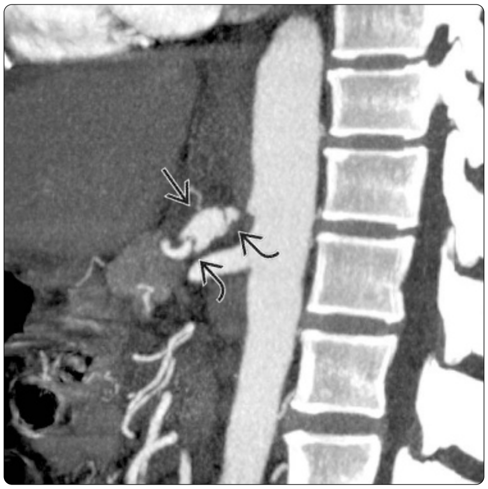


Hepatic Artery Aneurysm: Post Embolization (Arteriogram via GDA)

Segmental Arterial Mediolysis (Initial CECT Evaluation)

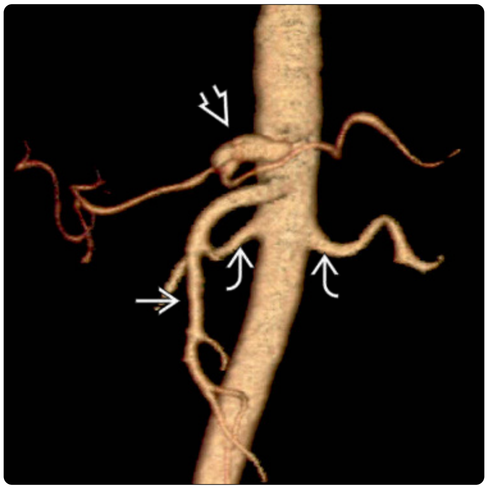


Segmental Arterial Mediolysis (Sagittal CT Reconstruction)

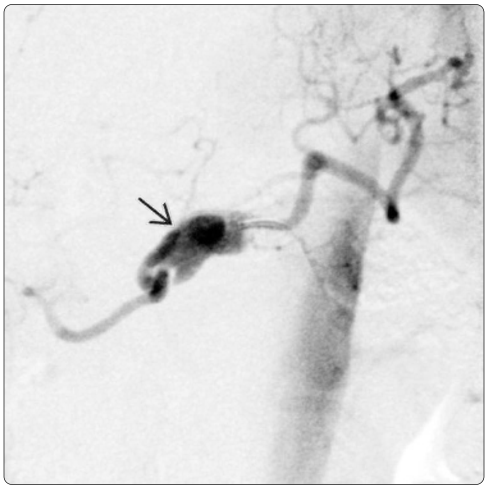


(Left) *An axial CECT in a patient presenting with acute worsening of chronic abdominal pain shows free intraabdominal fluid* ↪*. The celiac trunk is dilated and has a linear cleft* → *suspicious for an arterial dissection.* **(Right)** *A sagittal CT reconstruction better shows the abnormal appearance of the celiac trunk. At least 2 dissections* ↪ *are evident, along with a localized aneurysm* →*. Segmental arterial mediolysis is characterized by dissecting aneurysms that may affect only portions of the artery where there is deficient media.*

Segmental Arterial Mediolysis (3D CTA Reformation)

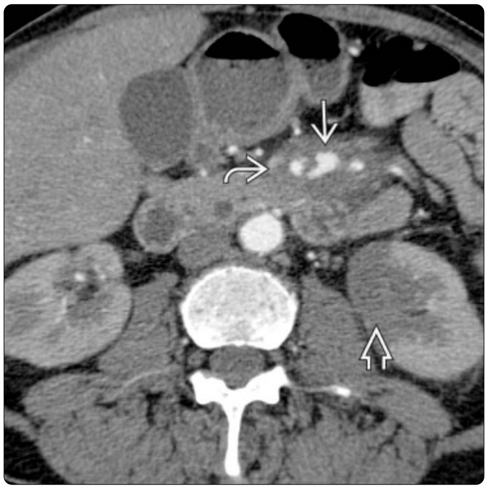


Segmental Arterial Mediolysis (Selective Celiac Artery DSA)

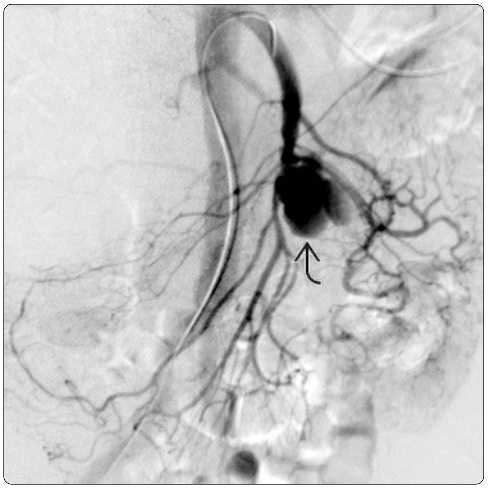


(Left) *3D CTA reformation of the aorta shows SMA* → *and renal arteries* ↪ *are normal, unlike the celiac artery* ⇨*. Segmental arterial mediolysis (SAM) may be confined to a single artery or may involve multiple arteries. The celiac artery is most frequently involved, followed by the SMA and renal arteries.* **(Right)** *The celiac artery DSA shows that, unlike fibromuscular dysplasia (FMD), this particular lesion* → *is focal. Although SAM may be difficult to differentiate from FMD, the latter involves the mesenteric arteries in only 9% of cases.*

Mycotic Aneurysm (Initial CECT Evaluation)



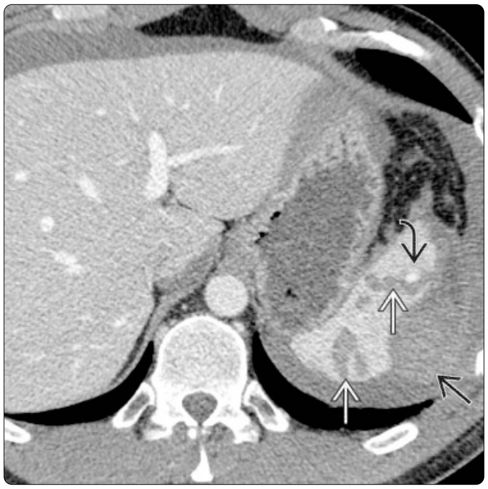
Mycotic Aneurysm (DSA of SMA)



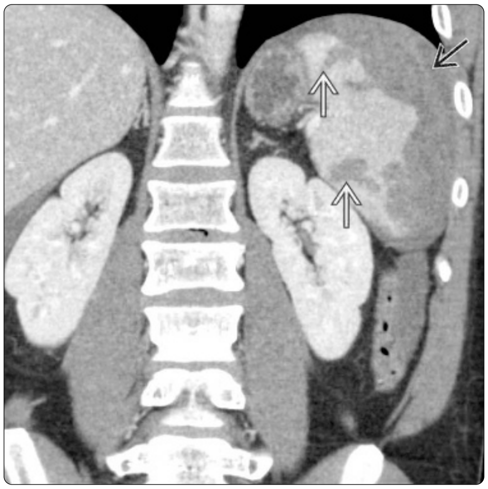
(Left) *An axial CECT in a patient with fever, leukocytosis, and severe flank and abdominal pain shows a left renal infarction* ⇨ *and a low-attenuation mass* ↪ *surrounding abnormally enlarged distal branches* → *of the SMA. The combination is worrisome for septic embolization resulting in a mycotic SMA aneurysm.* **(Right)** *The lobulated saccular aneurysm* ↪ *is consistent with a mycotic aneurysm. Management is surgical, in combination with antibiotic therapy.*

(Left) *An axial CECT in a hypotensive patient after blunt trauma shows multiple splenic lacerations ➡ and a focal contrast collection ↪ suspicious for pseudoaneurysm. There is a subcapsular hematoma with central high attenuation →, consistent with bleeding.* **(Right)** *The coronal CT reconstruction shows the extent of the splenic lacerations ➡ and the subcapsular hematoma →. Hepatic and splenic lacerations are managed conservatively but may require laparotomy or intervention.*

Splenic Fracture (Initial CECT Evaluation)

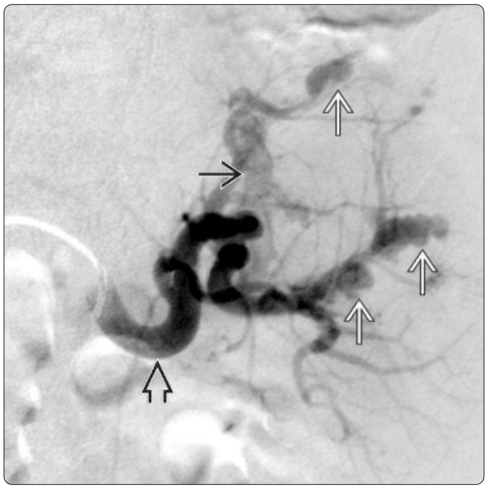


Splenic Fracture (Initial CECT Evaluation)

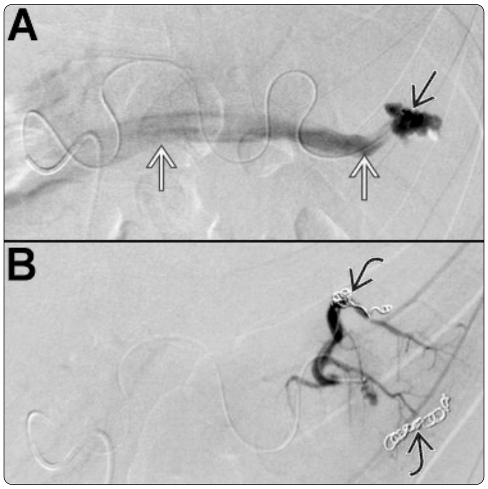


(Left) *Due to hypotension and a falling hematocrit, the patient underwent splenic artery ⇨ DSA, which shows contrast extravasation → and multifocal arterial abnormalities that could represent pseudoaneurysms ➡.* **(Right)** *(A) After the placement of a microcatheter distally in the arterial branch supplying the dominant abnormality → in the spleen, DSA was obtained. This shows immediate filling of the splenic vein ➡, indicating a traumatic arteriovenous fistula. (B) Coils ↪ were placed in the 2 main abnormal areas in the spleen.*

Splenic Fracture (Selective Splenic Artery DSA)

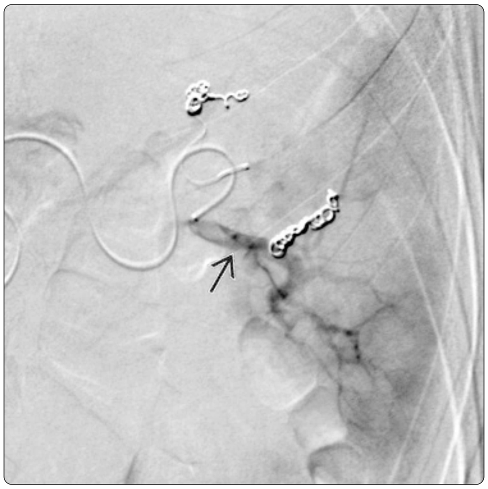


Splenic Fracture: Embolization via Microcatheter (DSA)

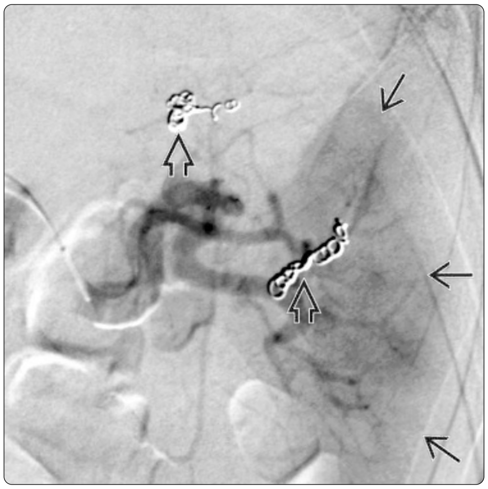


(Left) *Following embolization of both the arteriovenous fistula and a pseudoaneurysm that was shown to be the source of extravasation, the hemodynamics of the patient improved significantly. Additional splenic artery branches → were evaluated with DSA, but no other sources of bleeding were found.* **(Right)** *DSA following coil embolization ⇨ shows no pseudoaneurysms or sites of extravasation. Because of the selective nature of the embolization, there is still considerable splenic tissue → preserved.*

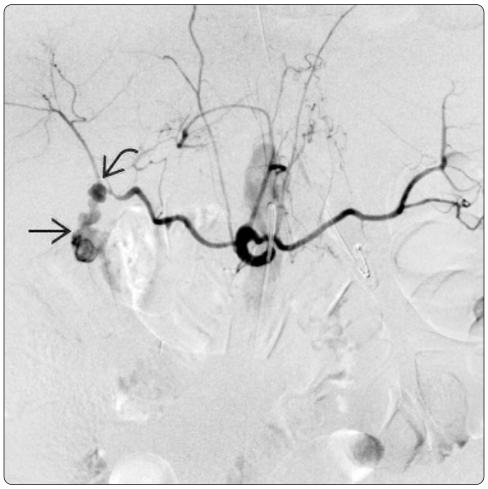
Splenic Fracture (Evaluation of Additional Branches)



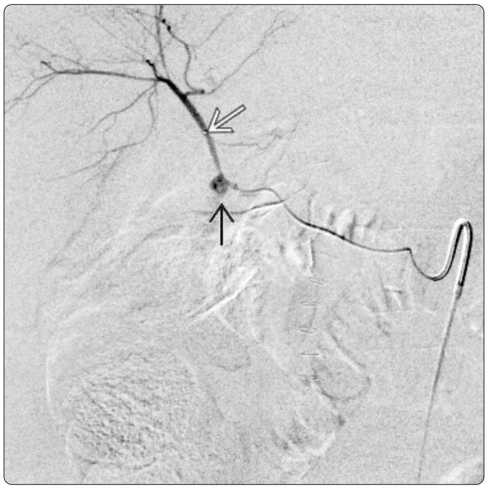
Splenic Fracture Treatment: Post Embolization (DSA)



Hemorrhage From Arterial Injury (Selective Celiac Artery DSA)

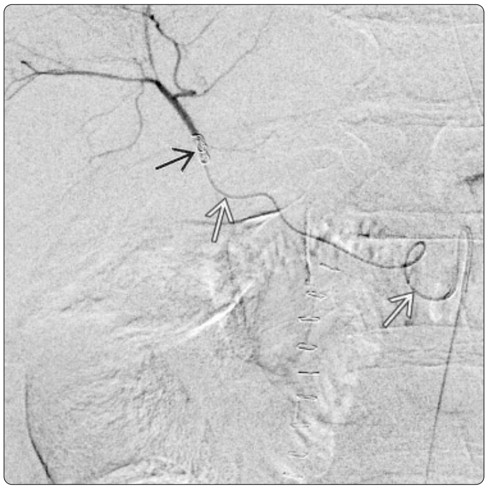


Hemorrhage From Arterial Injury (DSA With Coaxial Microcatheter Distally)

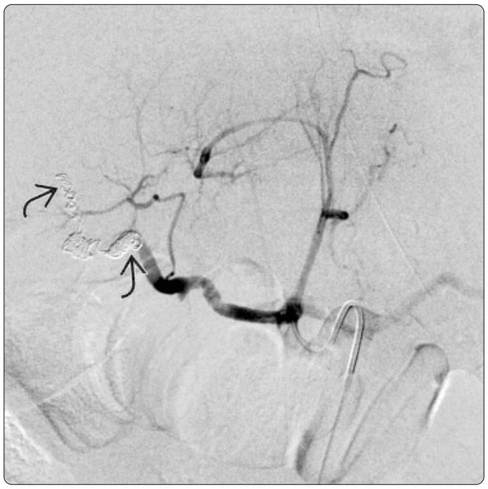


(Left) *This patient underwent a Whipple procedure for pancreatic cancer, with an incidental cholecystectomy, and developed abdominal pain and hypotension 1 week later. Celiac artery DSA shows extravasation → arising from a pseudoaneurysm ↪ of the proper hepatic artery. There is diffuse arterial vasoconstriction due to the hypotension from active bleeding.* **(Right)** *A coaxial microcatheter was introduced, and the tip ➡ was placed beyond the pseudoaneurysm → in preparation for coil embolization.*

Hemorrhage from Arterial Injury: Coil Embolization via Microcatheter (DSA)

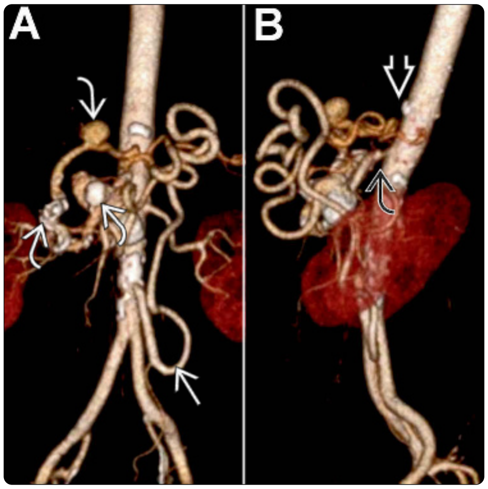


Hemorrhage From Arterial Injury: Post Embolization (Celiac DSA)

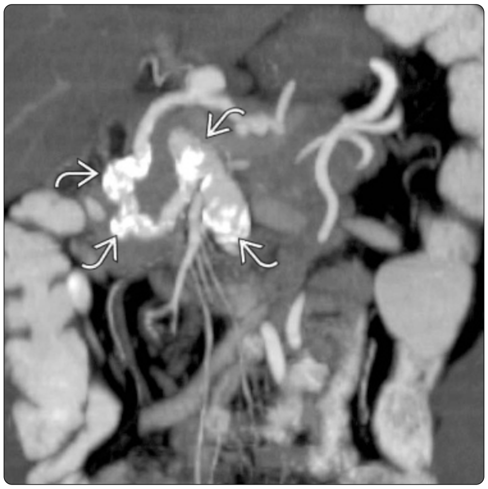


(Left) *Microcoils → were placed in the hepatic artery via the microcatheter ⇨. It is important during embolization that the coils are placed both proximal and distal to the lesion, as this prevents reperfusion in either an antegrade or retrograde fashion. In an actively bleeding hypotensive patient, coil embolization of the injured artery can rapidly improve hemodynamics.* **(Right)** *Celiac artery DSA after embolization shows that the coils ↪ were placed bridging the pseudoaneurysm, and there is no longer any extravasation.*

PDA Aneurysms (3D CTA Reformation)



PDA Aneurysms (Coronal CTA Reconstruction)



(Left) *(A) Coronal and (B) sagittal images (different patient) show multiple PDA aneurysms ➦. There are celiac artery occlusion ⇨ and SMA stenosis ↪. The PDA and inferior mesenteric ➡ artery are hypertrophied due to providing collateral flow to the celiac and SMA vascular beds.* **(Right)** *Reconstructions show large aneurysms ➦ that have a substantial rupture risk. They result from increased collateral flow in the presence of celiac or SMA stenosis or occlusion.*

Renal Arteries: Revascularization

KEY FACTS

PREPROCEDURE

- Main etiologies of renal artery stenosis (RAS)
  - Atherosclerosis (90%)
    - Causes renal insufficiency ± accelerated hypertension (HTN) ± flash pulmonary edema
  - Fibromuscular dysplasia (FMD) (10%)
    - Causes HTN; renal insufficiency rare
- Indications for treatment
  - At least 50% RAS **plus** uncontrollable HTN, worsening renal function, or recurrent flash pulmonary edema **despite** optimal medical therapy

PROCEDURE

- Atherosclerotic renal artery ostial stenosis
  - Stenting required for durable positive outcome
    - Stent should protrude 1-2 mm into aortic lumen
- FMD
  - Angioplasty alone
  - Stent placement only for significant dissection or vessel rupture
- Acute renal artery ischemia
  - Short-term catheter directed thrombolysis
  - Aspiration thrombectomy

POST PROCEDURE

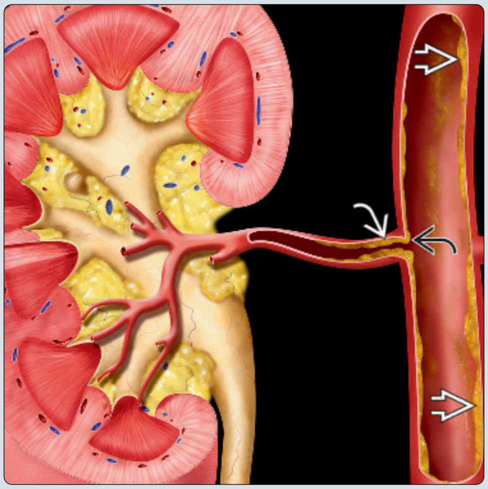
- Optimal postprocedure medical management essential
  - Vigilant post procedure BP monitoring
- Surveillance ultrasound: 2 weeks, 6 months, annually

OUTCOMES

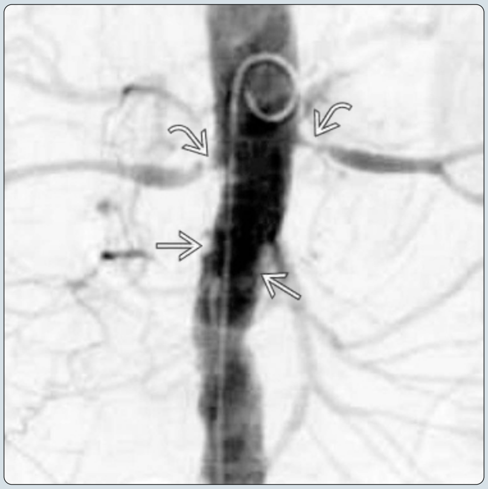
- Atherosclerotic RAS
  - Better BP control: ~ 2/3
    - Cure of HTN rare
  - Stabilization or improvement in renal function: ~ 3/4
- FMD
  - Cure of HTN: ~ 50%
  - Better BP control: ~ 90%

(Left) *Graphic shows narrowing of the proximal portion of the right renal artery caused by atherosclerotic plaque* ➡ *that extending to the ostium* ⇨*. Additional atherosclerotic plaques are seen throughout the aorta* ➡*.* **(Right)** *DSA shows severe bilateral proximal renal artery stenoses* ➡ *as well as other scattered atherosclerotic plaques* ➡*. Atherosclerotic renal artery stenoses typically affect the proximal 1/3 of the renal artery, as in this example.*

Atherosclerotic Renal Artery Stenosis (Graphic)

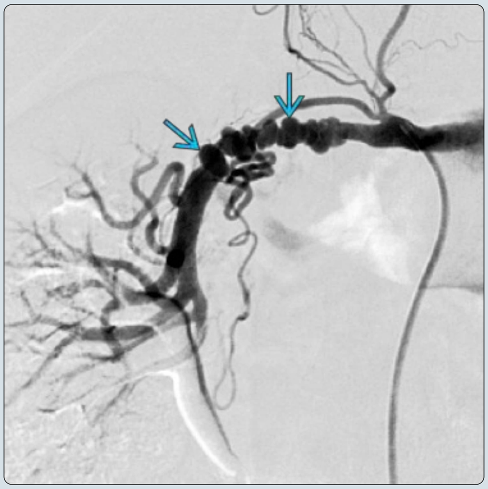


Atherosclerotic Renal Artery Stenosis (Aortogram)

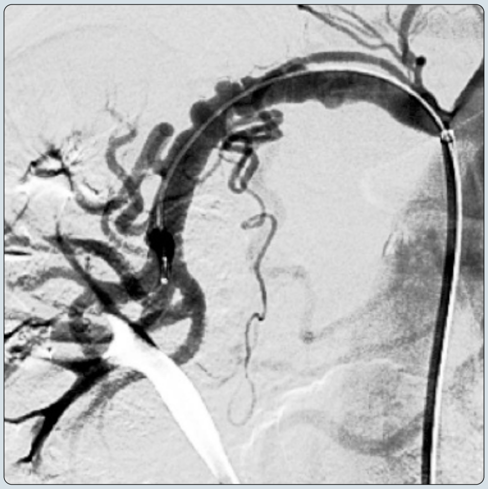


(Left) *Right renal artery angiogram shows beading of the mid portion of the right renal artery* ⇨*. FMD is a noninflammatory and nonatherosclerotic vasculopathy. Medial FMD accounts for 80-90% of the cases with a typical string of beads appearance.* **(Right)** *Balloon angioplasty is the treatment of choice. Stents are reserved for complications of balloon angioplasty, such as flow limiting dissection or vessel rupture.*

Renal Artery FMD (Initial Angiogram)



Renal Artery FMD (Post Balloon Angioplasty)



TERMINOLOGY

Definitions

- **Renal artery stenosis (RAS)**: Fixed narrowing of renal artery (main or branch vessels)
    - May lead to refractory hypertension (HTN), ischemic nephropathy, &/or pulmonary edema
- **Renal vascular HTN**: HTN due to RAS
    - **Accelerated HTN**: Previously controlled HTN now poorly controlled despite multiple additional medications
    - **Malignant HTN**: Uncontrolled HTN associated with acute end-organ damage
    - **Refractory HTN**: Continued HTN despite optimal doses of 3 drugs of different classes
- **Ischemic nephropathy**: Declining renal function and atrophy caused by poor renal perfusion

Epidemiology/Pathophysiology of Renal Artery Stenosis

- **Epidemiology**
    - Major cause of secondary HTN
        - Causative in 0.5-10.0% of all patients with HTN, ~ 30% of patients with accelerated HTN
    - Ischemic nephropathy contributory in ~ 25% of patients requiring hemodialysis
    - High prevalence in patients with atherosclerosis
        - 15-30% in coronary artery disease
        - 22-59% in peripheral artery disease
- **Pathophysiology**
    - Stenosis causes decreased renal perfusion
        - Renin released by juxtaglomerular cells
        - Renin activates angiotensin II production
        - Angiotensin II production causes efferent arteriole constriction
            - ↑ angiotensin II increases glomerular hydrostatic pressure in order to maintain glomerular filtration rate (eGFR)
            - ↑ angiotensin II causes systemic HTN
            - ↑ angiotensin II causes aldosterone elevation leading to sodium/water retention
- **Causes**
    - **Atherosclerosis**
        - Most common (90%)
            - M > F
            - > 50 years old
        - Affects ostium/proximal 1/3 of renal artery
        - Risk factors similar to atherosclerosis elsewhere
        - Stenting definitively better than percutaneous transluminal angioplasty (PTA) for ostial atherosclerotic lesions
    - **Fibromuscular dysplasia (FMD)**
        - 2nd most common cause of RAS (10%)
            - F > M (3-4:1)
            - Typically < 30 years old
        - Noninflammatory vasculitis
            - Involves mid and distal main renal artery
            - Also may involve segmental renal arteries
        - Medial fibroplasia most common subtype (80%)
            - Alternating areas of aneurysmal dilation give beaded appearance
        - Rarely leads to ischemic nephropathy or complete renal artery occlusion
        - Angioplasty alone effective
            - Stent reserved for PTA failure/restenosis/complications (i.e., dissection, rupture)
    - **Renal transplant arterial stenosis**
        - Affects 5-10% of transplants
        - Causes
            - External compression by peritransplant fibrosis
            - Kink points at anastomosis
            - Injury from vascular clamp used during surgery
    - **Other causes**
        - Takayasu arteritis, neurofibromatosis, mid aorta syndrome
        - Iatrogenic or traumatic injury
            - Vessel injury damages intima; causes thrombosis
        - Retroperitoneal tumor encasement/compression
    - **Acute renal ischemia**
        - Embolism from proximal source (e.g., atrial fibrillation or aortic plaque)
        - In situ thrombosis of stenotic renal artery
        - Iatrogenic from endovascular intervention
- Clinical reasons to suspect RAS
    - Drug-resistant HTN
    - Systolic readings in 170s-190s
    - HTN onset under 30 or after 50 years of age
    - Abrupt worsening of HTN or renal function
    - Concurrent known systemic atherosclerosis
    - Creatinine rise > 20% on angiotensin-converting enzyme inhibitor (ACE inhibitor)
- RAS and prognosis
    - RAS associated with increased cardiovascular events/mortality

PREPROCEDURE

Indications

- RAS **and** refractory HTN/progressively worsening renal function/"flash" pulmonary edema **despite** comprehensive medical therapy
    - No test reliably predicts whether improvement will result from intervention
    - Findings that may predict success
        - Renal length ≥ 8 cm
        - Recent decline in eGFR
        - Intact glomeruli on biopsy
- Significant RAS in single functioning kidney in patient with declining renal function
- Suspected or known FMD in patient with HTN
- Acute renal artery occlusion
    - Urgent revascularization may preserve renal function
        - Positive outcomes reported with procedure initiation up to 19 hours after event
            - Previous believed period of 1-3 hours before irreversible ischemia too short

Contraindications

- Absolute
    - Renal atrophy
        - No chance of functional recovery of atrophic kidney

  - Uncorrectable coagulopathy
  - Diffuse intrarenal vascular disease
- Relative
  - Ulcerated/unstable plaques
    - Risk of peripheral and renal embolization
    - Consider using embolic protection device
  - Difficult vascular access
  - Contrast allergy
    - Premedicate or use CO_2 or gadolinium
      - Avoid gadolinium if renal insufficiency present: risk of nephrogenic systemic fibrosis
      - Refer to ACR Manual on Contrast Media, 10.2, 2016
  - Significant comorbidities, poor overall prognosis, unstable patient

Preprocedure Imaging

- Doppler ultrasound
  - Main renal artery
    - Peak systolic velocity in renal artery ≥ 180 cm/second
    - Renal artery ratio (peak systolic renal artery/aortic velocity) > 3.5
  - Intrarenal arteries
    - Tardus parvus waveform
    - Prolonged acceleration time (> 0.07 seconds)
    - Loss of early systolic peak (ESP)
  - Advantages
    - Noninvasive, no contrast, no ionizing radiation
    - Used for follow-up after stenting/angioplasty
  - Disadvantages
    - Mid/distal renal artery difficult to visualize
      - Common location of stenosis in FMD
- Computed tomography angiography
  - Disadvantages
    - Potential for contrast-induced nephropathy
    - Ionizing radiation
- Magnetic resonance angiography
  - Disadvantages
    - High cost, long exam time, low availability
    - Overestimation of stenosis/false-positive tests
    - Nephrogenic systemic fibrosis risk
    - Limited visualization of accessory renal arteries
    - Metallic stents yield artifact
- ACE inhibitor radionuclide scintigraphy
  - RAS: Reduction of tracer uptake > 10% &/or prolongation of Tmax by 2 minutes after ACE-I administration
  - Rarely used in modern practice
- Digital subtraction angiography (DSA)
  - Gold standard
  - Advantages
    - High-quality images
    - Treat lesion concurrently
    - Selective renal DSA uses small contrast volumes
    - Can measure transstenotic gradient
  - Disadvantages
    - Invasive
  - Usually not performed unless performing intervention

Getting Started

- Things to check
  - Check for presence of accessory renal artery: Present in 25-30% of population
    - Stenotic accessory renal arteries can cause renal vascular HTN
  - Allergies
  - Labs: Prefer platelets > 50,000, INR ≤ 1.8
  - eGFR
    - Patients often with low/declining eGFR
- Medications
  - Hold antihypertensives on day of procedure
    - Manage BP only with short-acting medications, due to potential for precipitous drop in BP after intervention
  - 4,000 U loading dose of IV heparin once access obtained
  - Consider aspirin and Plavix loading dose
    - Clopidogrel: 300 mg
    - Aspirin: 81 mg or 325 mg
  - Prehydrate with IV normal saline for 4-6 hours for patients with renal insufficiency
- Equipment list
  - Micropuncture set
  - Catheters/sheaths
    - Flush catheter
      - Prefer Omniflush catheter to pigtail catheter
      - Pigtail disperses contrast over wider area necessitating higher volumes of contrast
    - Selective catheter
      - Cobra-2
      - Simmons/SOS (caudally angled renal artery)
    - Guiding catheter/guiding sheath
      - Permits small volume of contrast injection during stent during placement
      - Safer/more controlled delivery of stent
      - Base sheath shape on angulation of renal artery off aorta
      - Ansel 1 sheath commonly used
  - Guidewires
    - Initial 0.035" guidewire (Bentson)
    - Hydrophilic guidewire
    - Atraumatic/floppy tip guidewire for traversing stenosis
    - 0.014-0.018" guidewire (balloon-mounted stent)
  - Angioplasty balloons
    - Low profile
    - Match balloon and lesion lengths
    - Monorail if possible
  - Balloon-mounted stents
    - High radial force balloon-mounted stent
      - Typically uses 0.014-0.018" guidewire
      - Introduced coaxially via guiding catheter
      - Typical length: 1.5-2.0 cm
      - Typical width: 5-7 mm
    - Advantage of drug eluting stents or balloon-mounted covered stents (Atrium iCAST) uncertain
  - Embolic protection devices
    - Not in current clinical use for renal arteries
      - Designed for longer vessels (carotid)
      - Early bifurcation of renal artery limits utility
    - Cholesterol emboli potential etiology of postprocedure GFR ↓
  - Isosmolar iodinated contrast

    - Use lowest volume possible given likely concurrent renal insufficiency
      - 1:2 dilution with normal saline for selective angiogram
  - CO_2 contrast
    - Use in cases of poor or declining renal function
    - Can perform entire case using only CO_2 if necessary

PROCEDURE

Patient Position/Location

- Prefer right common femoral artery (CFA)
- Can consider brachial or radial approach in cases of
  - Significant caudal angulation renal arteries
  - Tortuous or stenotic iliac arteries
- Renal transplant interventions
  - Ipsilateral CFA access for external iliac anastomosis
  - Contralateral CFA access for internal iliac anastomosis

Equipment Preparation

- Flush all catheters/sheaths/devices with heparinized saline
- Ensure bail-out equipment present
  - Covered stents
  - Embolization coils
  - Aortic occlusion balloon

Procedure Steps

- Obtain arterial access
- Consider abdominal aortogram
  - Avoid if preprocedure imaging available and shows renal artery origins and stenosis
  - Position flush catheter at T12-L1
  - 10-20 cc/second flow rate; 20-40 cc contrast volume
  - Perform at angle to profile renal ostium
    - Position x-ray beam perpendicular to ostium
      - Base on preprocedure imaging
      - If no preprocedure CT or MR: left anterior oblique (LAO) ~ 15° for right renal artery, AP for left renal artery
    - Stent will falsely project into aortic lumen on AP imaging but will in fact be too peripheral if ostium not properly profiled
- Administer heparin
  - 3,000-5,000 U
- Access to renal arteries, place guiding sheath
  - SOS "flick" technique
    - SOS-1 or SOS-2 catheter
    - Bentson wire
      - Long (16 cm) floppy tip of Bentson wire allows wire to extend out of catheter but not undo reverse curve
    - Form SOS catheter below renal artery origin
    - Place Bentson wire 1 cm beyond end hole of catheter
    - Advance wire and catheter simultaneously
    - Wire will "flick" from pointing caudally to horizontally when renal ostium entered
    - Advance wire into renal artery
    - Pull SOS catheter down to seat it into artery
    - Advance sheath (previously parked in iliac arteries) over wire and catheter up to, but not, into renal artery origin
    - Exchange Bentson wire for desired working wire
    - Remove SOS catheter
  - Feldman no-touch technique
    - Curved sheath, inner dilator, and angled glidewire advanced above renal artery ostium
    - Inner dilator removed, wire retracted to extend about 4 cm out of sheath
      - Sheath takes its predetermined shape
      - Angled glidewire placed against aortic wall keeping sheath from scraping against aortic plaque
    - Renal artery ostium probed for with 0.014" wire
  - Selective sheath placement
    - Place medium stiffness wire through catheter
      - Floppy atraumatic tip preferred
    - Remove catheter
    - Advance sheath with inner dilator into renal artery ostium
      - May cause trauma to renal artery
      - Plaque dislodgement/cholesterol emboli
      - Dissection
    - Withdraw slightly and perform angiogram
- Perform renal angiogram
  - Note length and severity of stenosis
    - Determine stenosis by comparing with normal caliber renal artery
      - Do not compare stenotic region with post stenotic dilation
      - Would cause false increase in significance of stenosis
  - Determine significance of stenosis
    - ≥ 70%: Treat
    - ≤ 50%: Treatment not likely indicated
    - If > 50% but < 80%
      - Correlation with pressure measurements
      - > 10% systolic pressure gradient significant
      - Note that catheter within stenotic artery exacerbate stenosis and falsely elevate gradient
  - Suspect accessory renal artery if part of renal parenchyma is not opacified by contrast
- **Renal artery stenting**
  - Treatment of atherosclerotic stenosis
- Consider giving nitroglycerin (100-200 μg) into renal artery to prevent vasospasm
- Prestent balloon angioplasty if necessary
  - Avoid if possible
    - Could lead to cholesterol emboli or dissection
  - Perform only if extremely severe stenosis to create adequate lumen for stent passage
- Select appropriate balloon-mounted stent
  - Typical length: 1.5 cm
  - Typical width: 5-7 mm
  - Stent should cover entire length of stenosis
- Position stent
  - Proximal end should extend 1-2 mm into aorta
    - If stent not extending past ostium, aortic plaque can cover ostium
    - If stent > 2 mm into aorta, may have difficulty reengaging renal artery if restenosis

  - May advance sheath into renal artery through stenosis to protect stent and subsequent retraction of sheath after stent in position
    - Disadvantage: Possible cholesterol emboli
    - Advantage: Avoids any risk of stent dislodgement
- Perform contrast injection to confirm satisfactory stent position prior to deployment
  - Create mask image with bony landmarks to help guide stent placement
- Inflate balloon until stent fully expanded
  - Deploys balloon-mounted stent
- Remove balloon
  - Ensure balloon fully deflated
    - If still minimally inflated, could move or dislodge stent
    - Consider advancing sheath into peripheral portion of stent over balloon to ensure balloon will not dislodge stent
- Perform completion DSA arteriogram
  - Determine technical success of stenting
  - Exclude complications
- Remove catheters/sheath
- Obtain hemostasis
- **Renal artery angioplasty**
  - 1st-line treatment for FMD
- Obtain arterial access: Note existence of iliofemoral FMD
- Perform aortogram
  - Renal insufficiency not as often seen in FMD compared with atherosclerotic RAS; limiting contrast volume not critical
- Select renal artery(ies), perform renal artery angiogram
  - FMD changes most often at mid portion of renal arteries
    - Long segment stenosis of mid renal artery is medial hypoplasia or intimal fibroplasia subtypes of FMD seen in very young patients
- Consider measuring pressures across lesion
  - Visual improvement after angioplasty often underwhelming
  - Drop in pressure gradient across lesion confirms success of procedure
- Advance guiding sheath by one of the methods described above into renal artery origin
- Administer heparin
- Select appropriately sized balloon
  - Base on normal renal artery diameter
- Perform angioplasty of lesion
- Perform post procedure angiogram ± repeat pressure measurement
- **Bilateral disease**
  - Generally accepted to treat both sides at once
    - Previously, dogma was against treating both kidneys in one setting; current complication rates are lower now due to lower profile systems
- Advantages of bilateral treatment in same sitting
  - 1 access puncture
  - Patients are not lost to follow-up
    - Technically successful treatment of one side likely would not lead to BP improvement
    - Patient may not follow-up for contralateral side given this lack of improvement
- Advantages of treating one side at a time
  - Allows recovery of renal function if medium or high volume of contrast used for one side
- **Acute renal artery artery occlusion**
  - Lytic infusion
    - Select renal artery, place multiside hole infusion catheter along length of occlusion
    - Pulse-spray 5- to 10-mg tPA over 5-10 minutes
    - Infuse tPA 2 mg/hour over next 1-2 hours
    - Repeat angiogram
      - Stent to treat underlying stenosis or to exclude residual clot
  - Aspiration thrombectomy
    - Select renal artery
    - Place sheath at orifice of renal artery
    - Perform aspiration thrombectomy using aspiration catheter or aspiration device (e.g., penumbra)
    - Consider stent placement to treat underlying stenosis or to exclude residual clot

Findings and Reporting

- Length and degree of original stenosis
- Technical success
  - Residual stenosis, stent position, wall contact, change in pressure gradient, change in cuff pressure
- Volume of contrast used
- Dimensions, type of stent
- Complications

Alternative Procedures/Therapies

- Surgical
  - Surgical revascularization rarely indicated if
    - Endovascular treatment not feasible
    - Concurrent abdominal vascular surgery planned
    - Complication/failed endovascular treatment
  - High complication rate
  - Nephrectomy
    - Considered for unilateral disease with small, poorly functioning kidney
- Other
  - Medical
    - **C**ardiovascular **o**utcomes in **r**enal **a**therosclerotic **l**esions (CORAL) trial
      - Prospective trial published in NEJM
      - Renal-artery stenting no benefit compared to comprehensive, multifactorial medical therapy for **initial** treatment of presumed atherosclerotic renovascular HTN
      - Continued role for stenting in significant HTN or renal decline despite appropriate medical therapy
    - ACE-I and angiotensin II receptor blockers (ARB) are drugs of choice
      - Watch for decrease in eGFR > 20% (bilateral severe RAS)
      - Reversible with discontinuation
    - Atherosclerosis risk management
      - Smoking cessation, lipid lowering, etc.

POST PROCEDURE

Things to Do

- Overnight admission

- Hydrate with normal saline IV for 12 hours
  - Helps avoid contrast induced nephropathy
- Monitor for rebound hypotension
  - Acute drop in BP after stenting relatively common
- Clopidogrel: 75 mg daily for 3 months
- Aspirin: 81 mg or 325 mg for lifetime
- Consider adding low molecular weight heparin if sluggish renal artery flow present on final angiogram
- Follow serum creatinine
  - Expect small rise
- Optimal medical management after stent placement essential to good outcome
  - Adjust antihypertensive agents
    - ACE-I and ARB often better tolerated; no longer induce renal insufficiency
  - Medical management of atherosclerotic risk factors
    - Cholesterol/lipid control
    - Smoking cessation, exercise, diet
- Follow-up imaging
  - Duplex ultrasound
    - 1-2 weeks and 6 months post procedure
    - Annually for 3 years
    - Obtain additional ultrasounds as needed for worsening renal function or HTN

OUTCOMES

Problems

- Failure to improve HTN or eGFR; may be due to
  - Technical failure
  - Incidental RAS in patient with essential HTN
  - Irreversible renal damage; other cause of low eGFR
- Failure to salvage acutely ischemic kidney could be caused by delay in diagnosis, delay in initiation of procedure or delay in opening renal artery

Complications

- Most feared complication(s)
  - Flow-limiting renal artery dissection (~ 4%)
    - Caused by traumatic wire manipulation or dilation of rigid plaque
    - Treatment: Maintain guidewire in true lumen, place stent
  - Main renal artery perforation/rupture (~ 1%)
    - Causes: Improper balloon or stent size
    - Treatment
      - Maintain wire across lesion
      - Reverse anticoagulation with protamine
      - Inflate angioplasty balloon across leak for tamponade
      - Place covered stent
  - Renal parenchymal guidewire perforation
    - Causes: Advancing stiff glidewire too far, not keeping wire in complete field of view
      - Patients may complain of sudden flank pain during procedure
    - Treatment
      - Do **not** immediately withdraw wire; keep in place for access
      - Advance 4-Fr glide catheter over wire
      - Once in distal position, withdraw wire, perform angiogram
      - If evidence of vascular injury or extravasation, perform selective coil embolization
  - Stent malposition
    - Causes
      - Renal artery not profiled correctly during angiograms/deployment
      - Dislodgement of stent off balloon during advancement through tight stenosis
    - Treatment: Add additional stents or pull stent down into iliac artery and deploy
- Delayed complication(s)
  - Postprocedure decline in renal function (20% rate)
    - Renal cholesterol embolism
      - Caused by traumatic sheath/catheter placement into friable/mobile plaque
    - Contrast-induced nephropathy
      - Use lowest amount of iodinated contrast
      - Consider CO_2 use as contrast agent
      - Give adequate pre- and postprocedure hydration
  - In-stent restenosis (~ 10%)
    - Treatment options: Restenting/PTA
      - Restenting with covered stent likely most effective
    - Reported 60-month secondary patency rates after reintervention range between 66-98%
      - Type of reintervention affects patency rates
- Other complications
  - Vascular access complications
  - Contrast reaction

Expected Outcomes

- Atherosclerotic RAS
  - HTN
    - Cure rare (< 5%)
    - Better control, reduced medication (66%)
  - Renal insufficiency
    - Stabilization/improvement in function (75%)
  - Decreased activation of renin-angiotensin system may yield decreased cardiovascular events
- FMD: Excellent technical/clinical result
  - HTN cure: ~ 50%; improvement: > 90%
- Acute renal artery occlusion: Embolic/thrombotic
  - Kidney tolerates only short warm ischemia time
  - Only 14% of patients with posttraumatic occlusion of renal artery have return of normal renal function after endovascular revascularization

SELECTED REFERENCES

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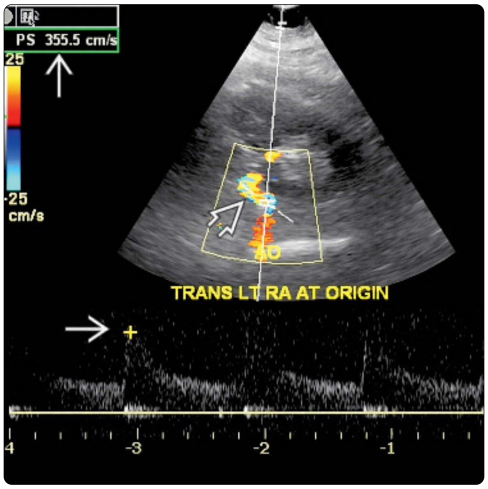
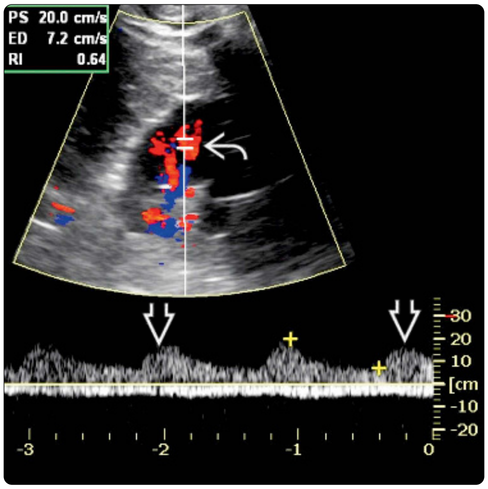
3. Mohan IV et al: The management of renal artery stenosis: an alternative interpretation of ASTRAL and CORAL. Eur J Vasc Endovasc Surg. 49(4):465-73, 2015
4. Cooper CJ et al: Stenting and medical therapy for atherosclerotic renal-artery stenosis. N Engl J Med. 370(1):13-22, 2014
5. Stone PA et al: Ten-year experience with renal artery in-stent stenosis. J Vasc Surg. 53(4):1026-31, 2011

(Left) *Ultrasound may confirm suspected renal vascular hypertension. Direct signs of a renal artery stenosis (RAS) include a peak systolic velocity ≥ 180 cm/second ➔ or a renal artery:aortic peak systolic velocity ratio ≥ 3.5. Turbulent flow is seen distal to the stenosis ⇨.* **(Right)** *The intrarenal arteries ↪ are also interrogated by US for indirect signs that would indicate an upstream stenosis. These include a tardus parvus waveform ⇨ and prolonged acceleration time (> 0.07 seconds) and loss of early systolic peak.*

Renal Artery Stenosis Diagnosis (Preprocedure Ultrasound)

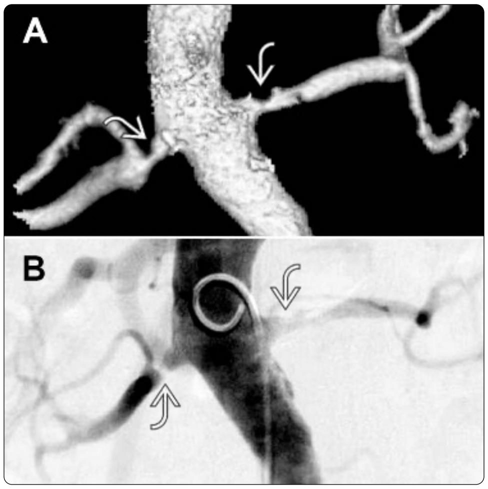


Renal Artery Stenosis Diagnosis (Preprocedure Ultrasound)

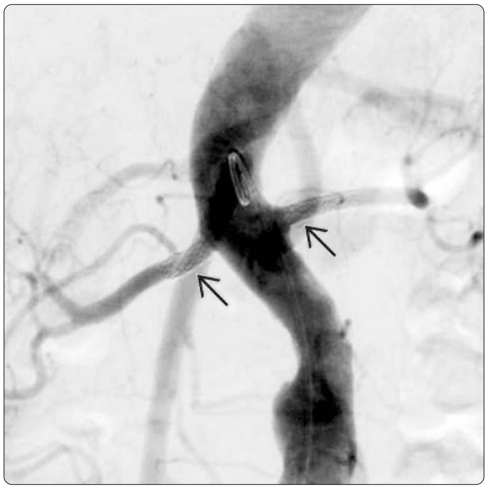


(Left) *3D CT angiography reconstruction (A) and corresponding DSA arteriogram (B) images show bilateral proximal renal artery stenoses ↪. Atherosclerotic disease typically affects the proximal renal arteries.* **(Right)** *Aortogram after bilateral balloon-mounted stent placement → shows no residual stenosis or occlusion. Both stents project into aortic lumen by 1-2 mm, which is considered to be ideal positioning. Treatment of bilateral stenoses in one setting may be performed if contrast volume is kept low.*

Renal Artery Stenosis (CTA and DSA Evaluations)

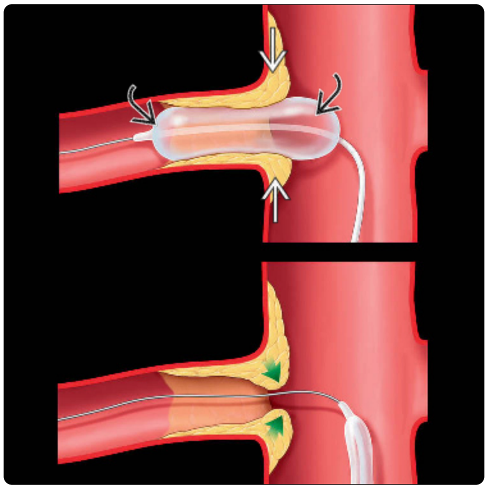


Renal Artery Stenosis (Post Treatment Angiogram)

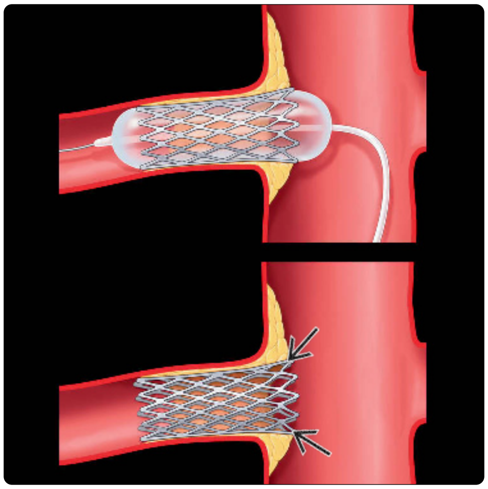


(Left) *Graphic shows that balloon angioplasty ↪ of an ostial atherosclerotic stenosis ⇨ is often ineffective, as the plaques will recoil upon deflation and removal of the angioplasty balloon.* **(Right)** *Stenting is superior to angioplasty alone in atherosclerotic disease. This graphic shows a balloon-mounted stent correctly placed at the site of the stenosis, projecting 1-2 mm → into the aortic lumen. This position prevents the aortic plaque from covering the proximal portion of the stent and prevents plaque recoil.*

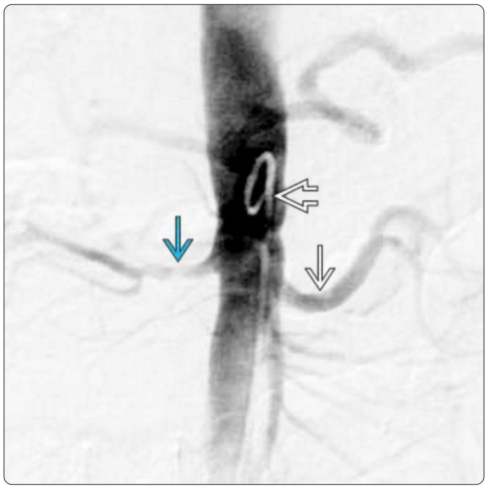
Ostial Atherosclerotic Stenosis (Treatment With Angioplasty)



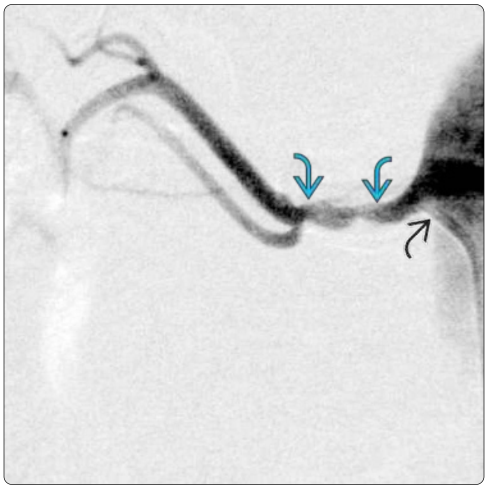
Ostial Atherosclerotic Stenosis (Treatment With Stenting)



Renal Artery Stent Procedure (Initial DSA Aortogram)

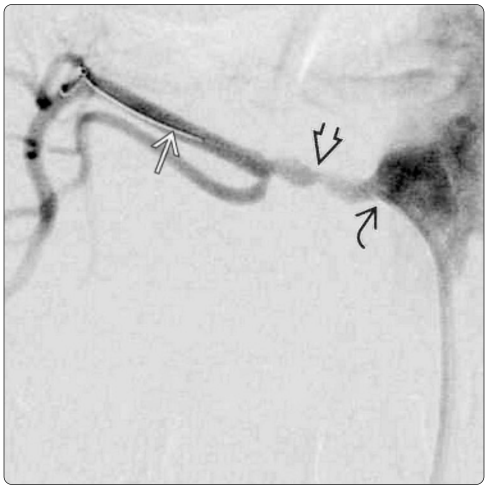


Renal Artery Stent Procedure (Selective Renal Artery Angiogram)

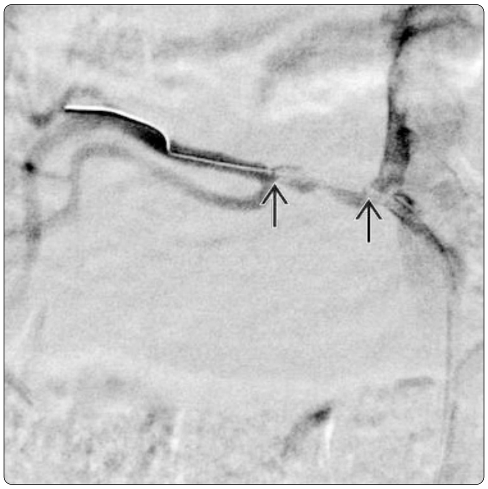


(Left) *A DSA aortogram is performed with a pigtail catheter* ➡ *positioned with the side holes at the level of the renal arteries. This shows a lengthy stenosis of the right renal artery* ⇨*. The left renal artery* ➡ *appears normal. No accessory renal arteries are identified.* **(Right)** *The pigtail was exchanged for a selective catheter whose tip* ⇨ *is positioned in the renal artery ostium. A selective DSA is performed. The stenosis and irregularity* ⇨ *is better defined by the selective renal arteriogram.*

Renal Artery Stent Procedure (Guidewire Through Lesion)

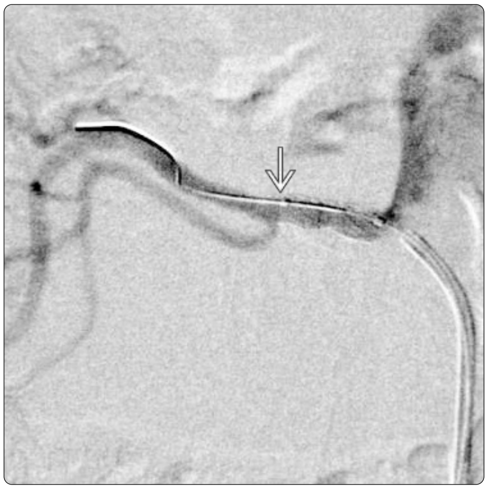


Renal Artery Stent Procedure (Balloon-Mounted Stent Placement)

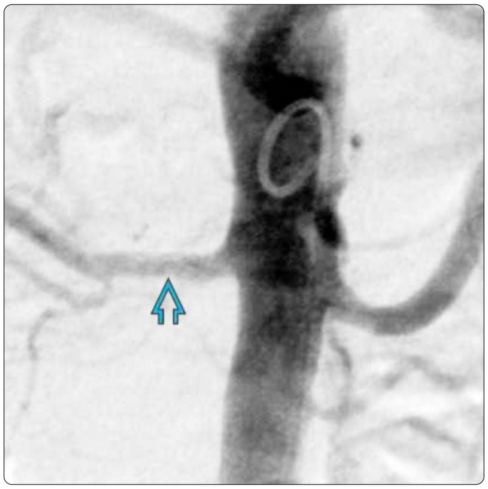


(Left) *After administering heparin, an atraumatic guidewire* ➡*, such as a tapered TAD wire, is advanced through the stenosis* ⇨*. An angled sheath* ⇨*, such as an Ansel sheath, is then advanced over the wire an into the renal ostium. Repeat angiography is then performed. Pressures can be measured, if desired.* **(Right)** *After the sheath is placed into stable position and the appropriately sized stent is selected, it is introduced into the stenosis* ⇨*. Repeat angiogram through the sheath can be performed to confirm desired location of the stent.*

Renal Artery Stent Procedure (Balloon-Mounted Stent Deployment)



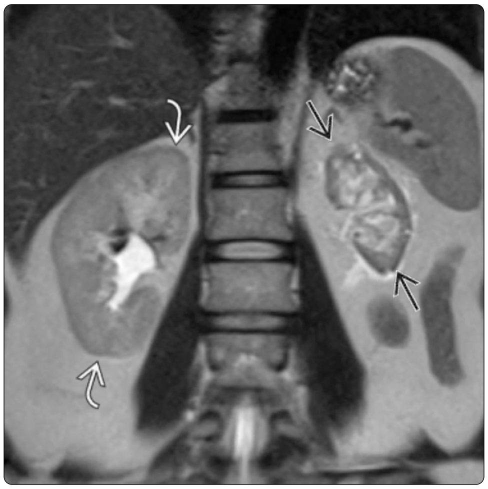
Renal Artery Stent Procedure (Completion DSA Arteriogram)



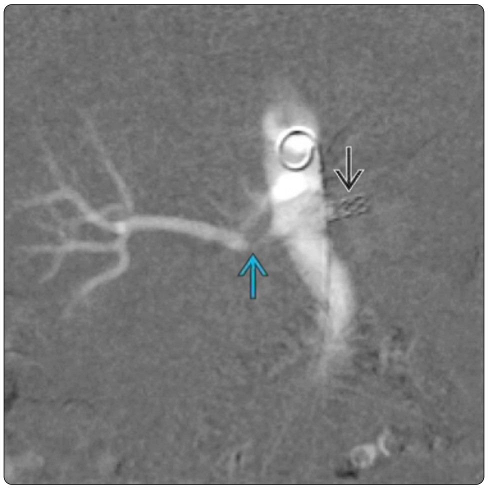
(Left) *Balloon-mounted stents enable precise placement, which is critical in RAS and especially in this case to land the distal portion of the stent* ➡ *just proximal to the early bifurcation of the main renal artery.* **(Right)** *Aortogram after stent* ⇨ *deployment shows a satisfactory stent position and no residual stenosis. Although hypertension is rarely (< 5%) cured in atherosclerotic RAS, better control is achieved in 2/3 of cases.*

(Left) *Coronal MR in a 47-year-old woman with rapidly worsening renal function shows a normal-appearing right kidney* ↪*, but ultrasound revealed right RAS. The atrophic left kidney* ⇨ *had previously been treated with a renal artery stent.* **(Right)** *Given the declining renal function, it was decided to perform the entire procedure with carbon dioxide. This initial aortogram shows occlusion of the left renal artery. Previously placed stent is seen* ⇨*. Severe right RAS is present* ⇨*.*

Renal Artery Stenosis (Pretreatment MR)

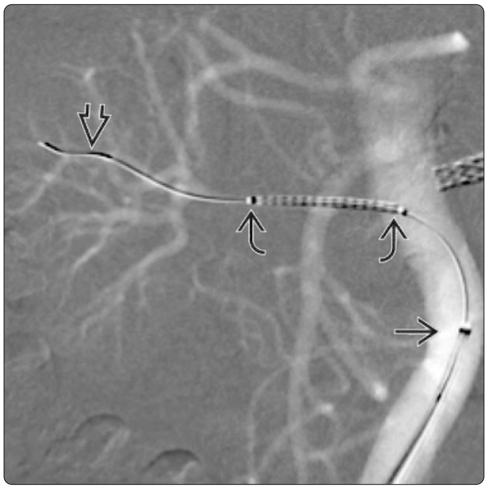


Carbon Dioxide Aortogram

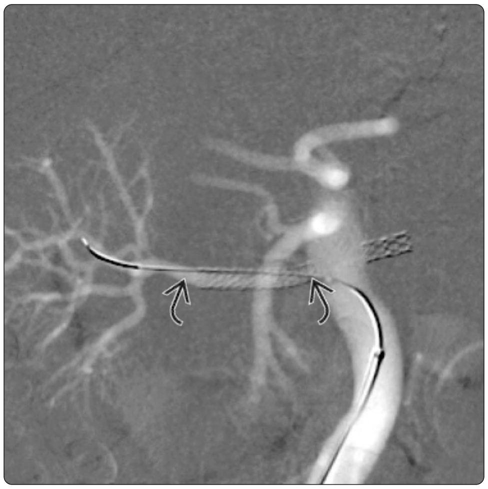


(Left) *After a TAD II wire* ⇨ *was advanced through the lesion, an Ansel sheath was advanced into the renal artery. An Atrium iCAST stent* ↪ *(balloon expandable covered stent) was then positioned to cover the stenosis and protrude slightly into the aortic lumen. The Ansel sheath* ⇨ *was then retracted.* **(Right)** *Post stent deployment* ↪ *aortogram shows no residual stenosis. Systolic gradient across the lesion dropped from 54 mm Hg to 0 after. The patient's renal function durably improved after the procedure.*

Carbon Dioxide Aortogram (Predeployment)

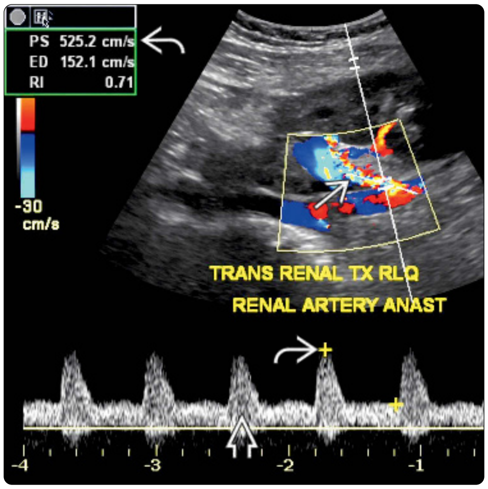


Carbon Dioxide Aortogram (Postdeployment)

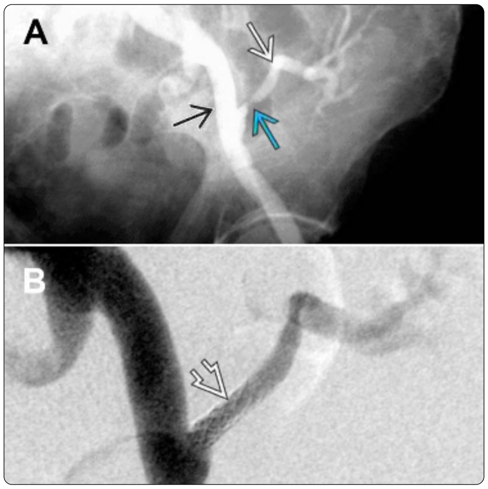


(Left) *There is an elevated peak systolic velocity* ↪ *of 525 cm/second, poststenotic turbulent flow* →*, and spectral broadening* ⇨ *at the transplant anastomosis, consistent with RAS in this dysfunctional allograft.* **(Right)** *The donor renal artery* → *is anastomosed end-to-side to the external iliac artery* ⇨*. (A) Angiogram shows a severe stenosis* ⇨ *of the donor renal artery near the anastomosis. (B) DSA after intervention shows a stent* ⇨ *placed across the stenosis with good results.*

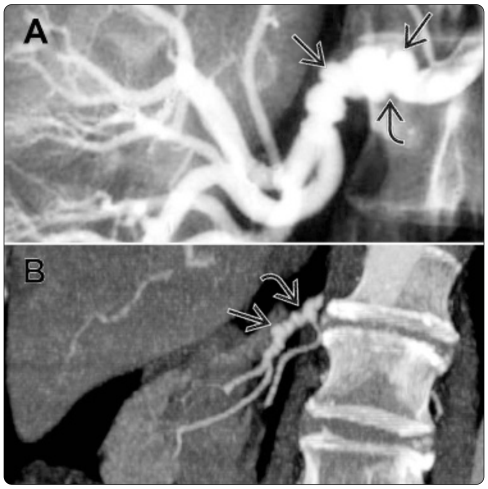
Transplant Renal Artery Stenosis (Preprocedure Ultrasound)



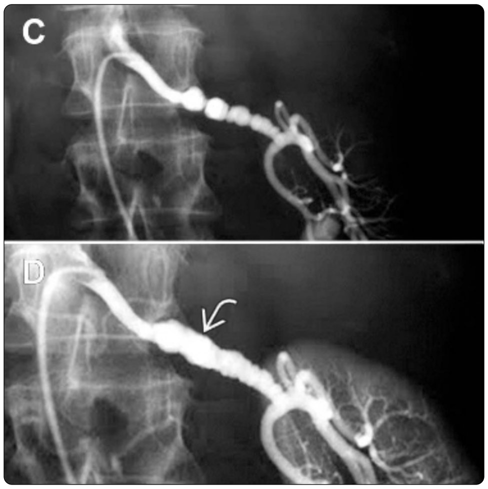
Transplant Renal Artery Stenosis (Initial Angiogram and Post Treatment Angiogram)



Fibromuscular Dysplasia (Imaging With Angiogram and CTA)

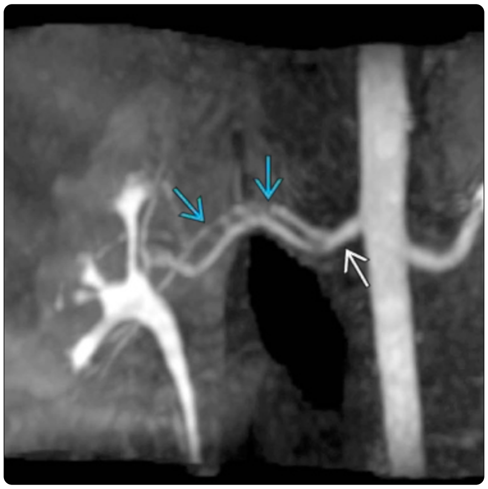


Fibromuscular Dysplasia (Treatment With Angioplasty)

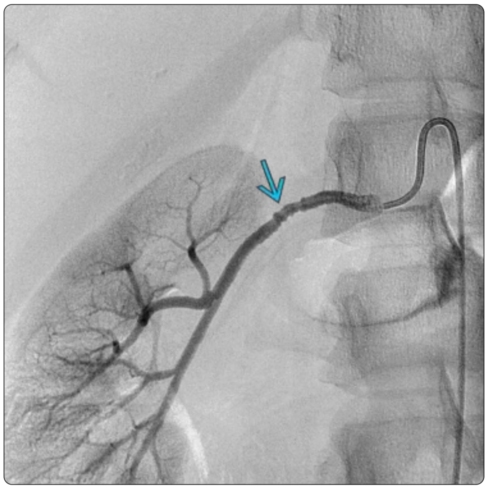


(Left) *FMD is the 2nd most common cause of RAS. Angiogram (A) and CTA (B) show the characteristic alternating stenoses ↪ and dilations ⇨. The mid portion of the renal artery is most characteristically affected.* **(Right)** *In the same patient, (C) renal artery angiography shows the classic appearance of FMD. (D) Angioplasty was performed with good results ↪. Mild residual irregularity of the artery is expected after angioplasty: Avoid the urge to over dilate or stent.*

Fibromuscular Dysplasia on MRA

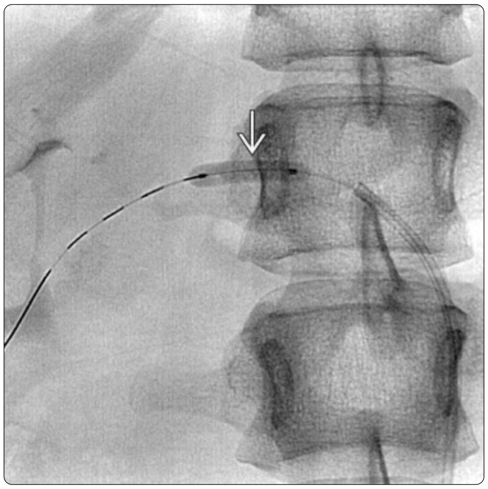


Fibromuscular Dysplasia (Selective Right Renal Artery Angiogram)

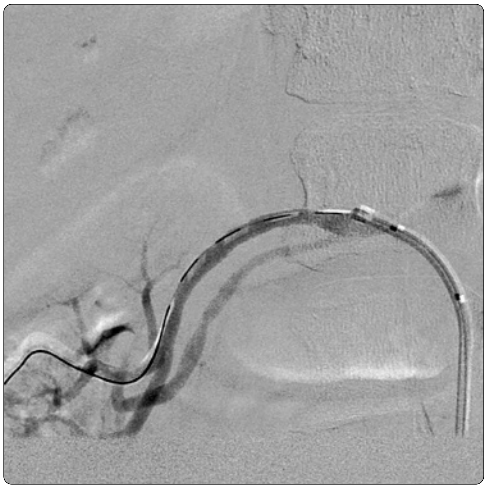


(Left) *This 31-year-old woman had rapid and new onset severe hypertension with systolic blood pressures > 200 mm Hg. MR angiography showed a beaded appearance of the upper pole right renal artery ⇨ with early bifurcation of the main renal artery ➡.* **(Right)** *A 5-Fr SOS-2 Omni catheter was used to select the superior branch of the right renal artery. A moderately long segment of mild luminal beading ⇨ is consistent with FMD. The previous MR may have overestimated the abnormality.*

Fibromuscular Dysplasia (Balloon Dilation)



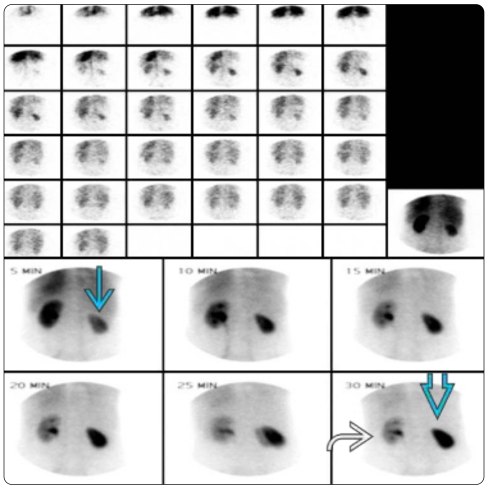
Fibromuscular Dysplasia (Postprocedure Angiogram)



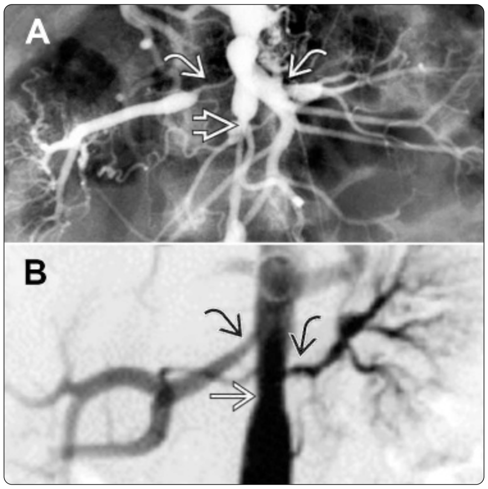
(Left) *Because of her severe hypertension, despite the mild angiographic appearance, it was decided to proceed with balloon angioplasty. After a wire was used to traverse the lesion, a 6-Fr Ansel sheath was advanced into the renal artery ostium. Balloon angioplasty was done with a 4-mm balloon* ➡. **(Right)** *After balloon dilation, a right renal postangioplasty arteriogram shows no significant residual narrowing or beading. This patient's hypertension resolved after treatment.*

(Left) *ACE-I scintigraphy is now rarely used to diagnose RAS. This scintigraphy shows the classic findings of right-sided RAS, including decreased initial uptake →* *and delayed retention ⇨ of radiotracer compared to the left kidney ↪.* **(Right)** *(A) In this patient with type 1 neurofibromatosis, there is bilateral RAS ↪ as well as stenosis of the abdominal aorta ➡. (B) In this patient with Takayasu arteritis, there is tapered narrowing of the renal arteries bilaterally ↪ and of the abdominal aorta ➡.*

ACE Inhibitor Scintigraphy (Right Renal Artery Stenosis)

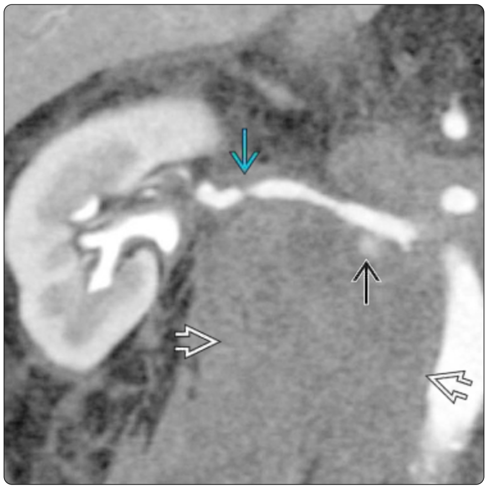


Rare Causes of Renal Artery Stenosis (Neurofibromatosis, Takayasu Arteritis)

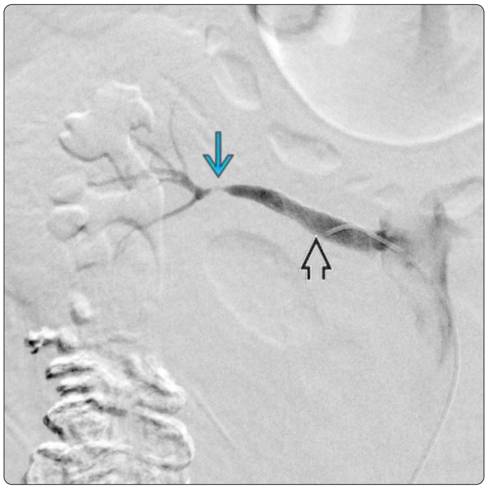


(Left) *CECT from a 49-year-old man with metastatic myofibroblastic sarcoma shows that the tumor eroded portions of the proximal renal artery, causing a pseudoaneurysm with contrast extravasation → leading to a large retroperitoneal hematoma ➡. The tumor was also encasing the distal renal artery and causing a focal stenosis →.* **(Right)** *After a covered stent was placed in the proximal renal artery ⇨ excluding the pseudoaneurysm, further treatment of the severe distal stenosis → was necessary.*

Renal Artery Tumor Encasement (Arterial-Phase CECT Imaging)

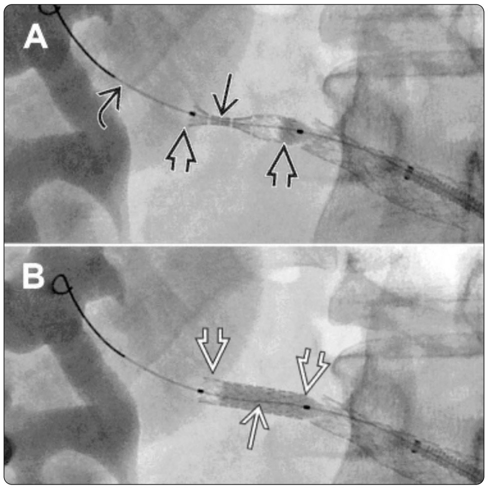


Renal Artery Tumor Encasement (DSA Arteriogram and Intervention)

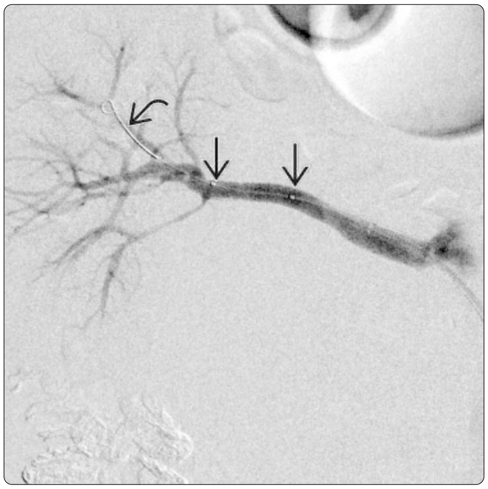


(Left) *(A) A guidewire ↪ was placed across the lesion, and a noncovered balloon-mounted stent ⇨ was positioned at the stenosis. Note the waist → caused by the tumor encasement. (B) The stent ➡ was then completely expanded by inflating the balloon ➡ upon which the stent was mounted.* **(Right)** *Final DSA shows no residual stenosis in the distal right renal artery after stent → placement. The guidewire ↪ was kept in place until confirmation of procedural success and exclusion of significant complications.*

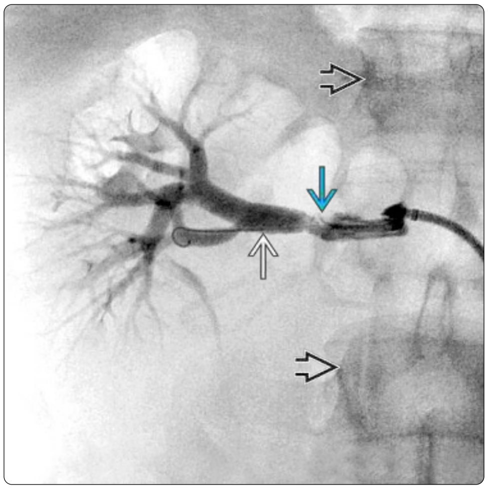
Renal Artery Tumor Encasement (Noncovered Stent Placement)



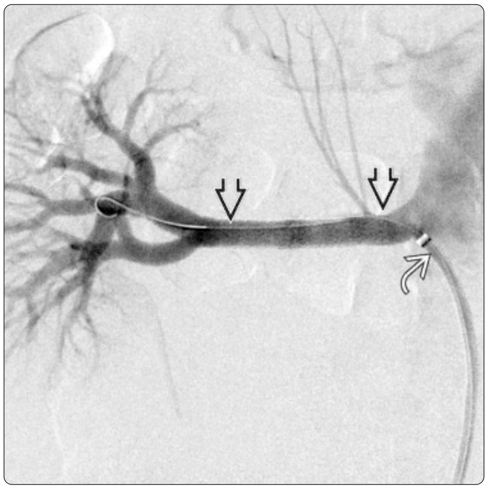
Renal Artery Tumor Encasement (Postintervention DSA Arteriogram)



Renal Artery Trauma (Deceleration Injury)

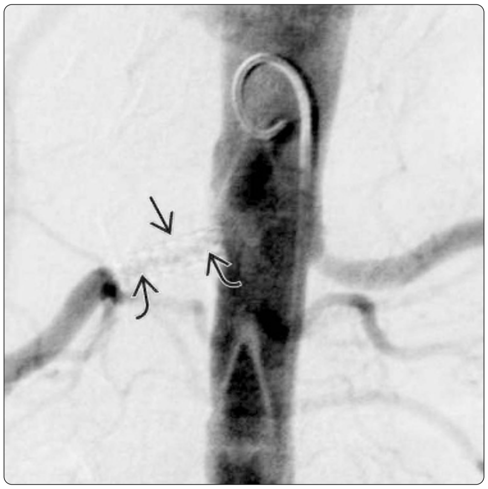


Renal Artery Trauma (Treatment With Covered Stent)

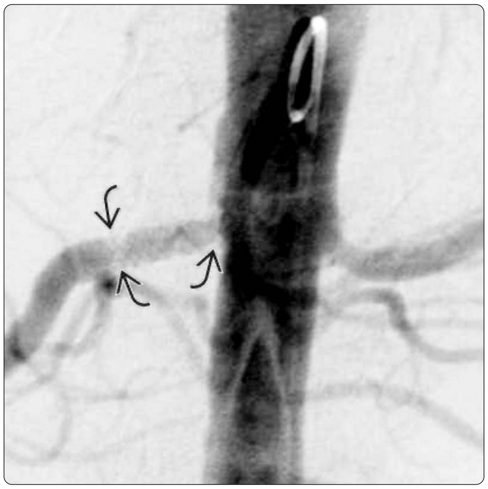


(Left) *The right renal artery ➡ crosses anterior to the spine ⇨ and is vulnerable to a stretching injury during severe deceleration, potentially leading to intimal injury and luminal irregularity ⇨ or dissection. This can lead to arterial thrombosis and irreversible renal ischemia if not treated promptly.* **(Right)** *A covered stent ⇨ was introduced via a guiding catheter ↪ and placed across the injured renal artery segment with resolution of the previously seen luminal irregularity.*

RAS Stent Placement Complication (Development of In-Stent Stenosis)

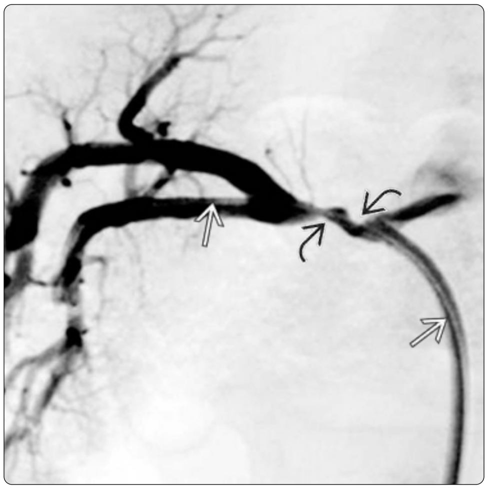


RAS Stent Placement Complication (Treatment With Angioplasty)

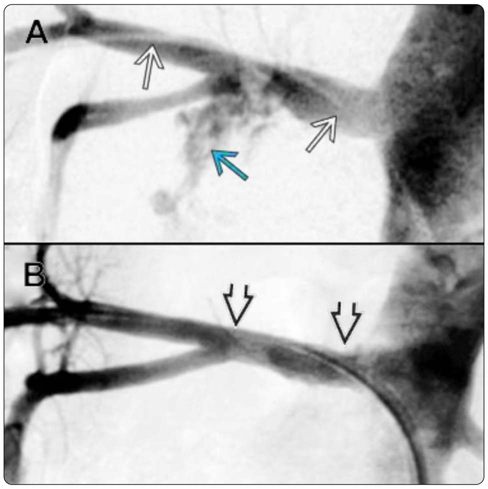


(Left) *DSA aortogram obtained in a patient who previously had a right renal artery stent ⇨ shows a high-grade in-stent stenosis with only a minimal residual lumen ↪. Treatment options for an in-stent stenosis include restenting with a covered stent or balloon angioplasty.* **(Right)** *DSA after balloon angioplasty within the right renal artery stent shows significant interval improvement with some scattered areas of residual in-stent stenosis ↪.*

Complication of Angioplasty (Renal Arterial Rupture)



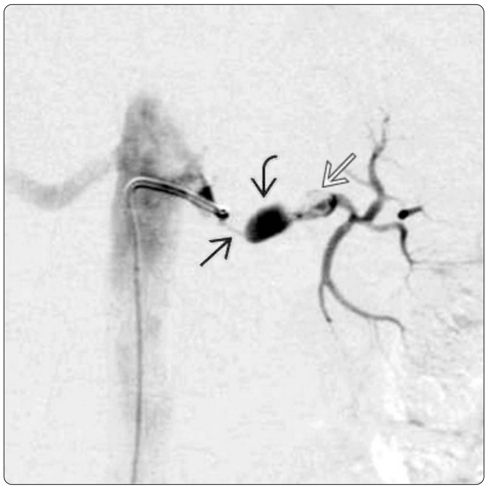
Complication of Angioplasty (Treatment With Covered Stent)



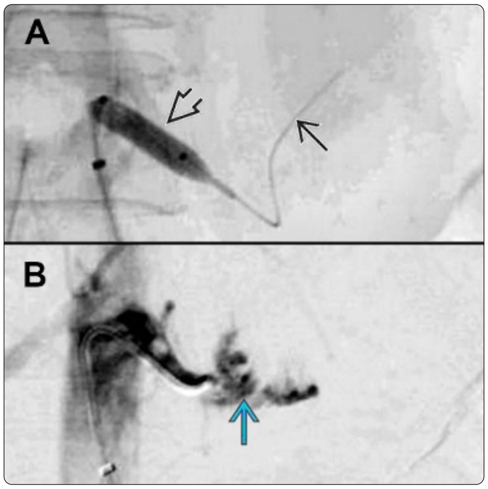
(Left) *Selective right renal artery DSA shows a high-grade complex stenosis of the proximal right renal artery ↪. A guidewire ➡ has been passed through the stenotic lesion, and the tip has been positioned distally.* **(Right)** *(A) Postangioplasty DSA shows extravasation ⇨ of contrast. Fortunately, the guidewire ➡ position was maintained. (B) This allowed a covered stent ⇨ to be placed for treatment of the arterial rupture. The repeat DSA shows no contrast extravasation as well as only a minimal residual stenosis. (Courtesy G. Narayanan, MD.)*

(Left) *Left renal DSA shows a proximal high-grade stenosis → adjacent to a bilobed aneurysm ↷ with thrombus distally ➡ within the 2nd component of the aneurysm.* **(Right)** *(A) Over a guidewire →, PTA of the stenosis was performed. The balloon ⇨ used was inappropriately sized, chosen to match the size of the adjacent aneurysm. (B) Post-PTA DSA shows contrast extravasation →. The guidewire had been removed. No endovascular options were available and emergent nephrectomy was required.*

Complication of Angioplasty (Renal Artery Rupture)

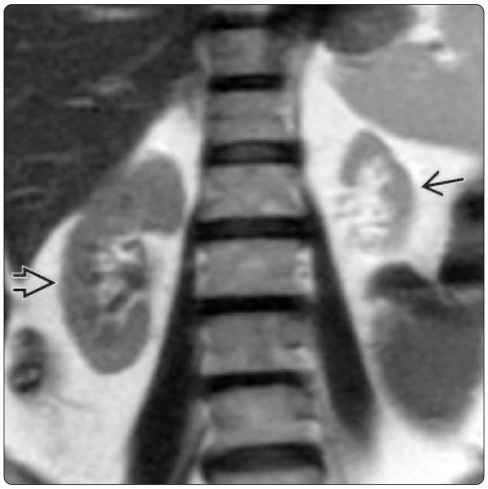


Renal Artery Rupture During PTA (Oversized Balloon, No Guidewire)

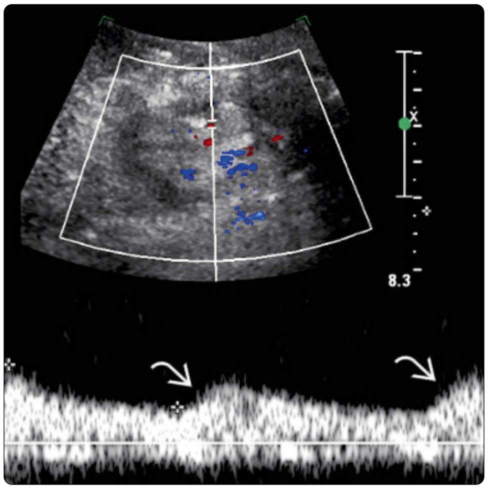


(Left) *This 60-year-old patient had poorly controlled hypertension despite multiple antihypertensive medications. Recently, her serum creatinine rose from a baseline of 1.0 mg/dl to 1.8 mg/dl. These coronal MR images show an atrophic left kidney → and normal-appearing right kidney ⇨.* **(Right)** *Duplex ultrasound showed a proximal right renal artery velocity of 382 cm/second and an aortic velocity of 76 cm/second for a renal artery:aorta ratio of 5. Marked parvus tardus waveform of the intrarenal arteries was seen ↷.*

Renal Artery Stent Fracture (Preprocedure Imaging MR)

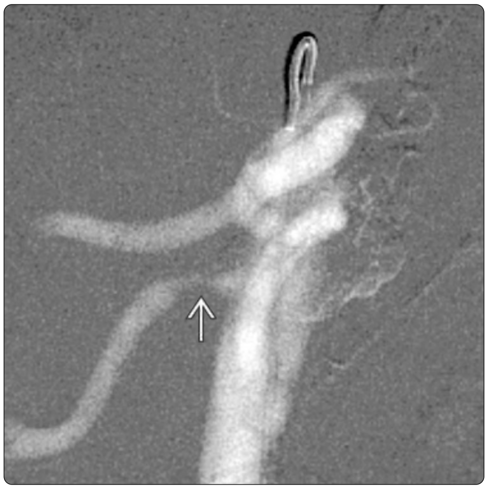


Renal Artery Stent Fracture (Preprocedure Imaging-Duplex Ultrasound)

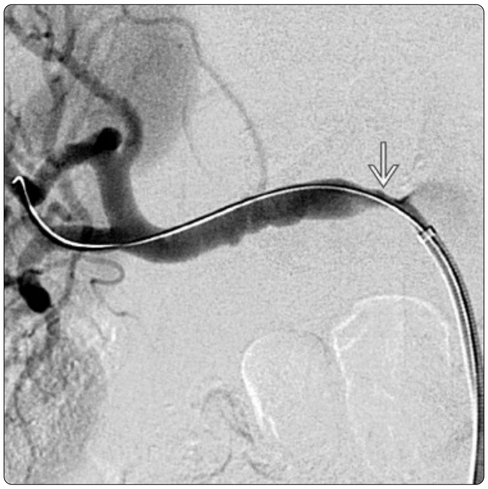


(Left) *Given her rising creatinine, CO_2 was used where possible. Initial aortogram through an Omniflush catheter shows the severe right RAS ➡. The left renal artery is not seen and likely occluded.* **(Right)** *An 0.018" floppy tip wire was advanced into the renal artery, over which a 45-cm 6-Fr Ansel sheath was placed. A selective right renal angiogram through this sheath showed severe ostial stenosis ➡. Pressures were measured across the stenosis with an initial gradient of 52 mm Hg*

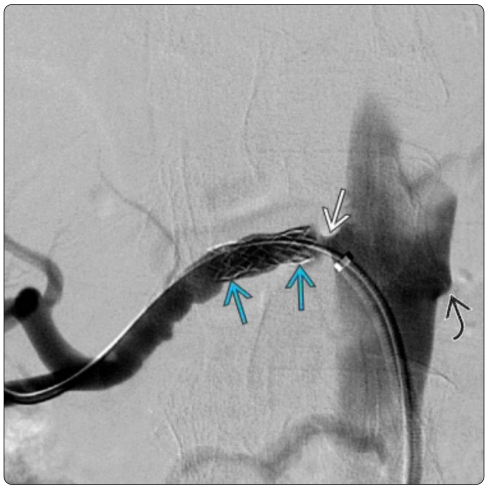
Renal Artery Stent Fracture (CO_2 Aortogram)



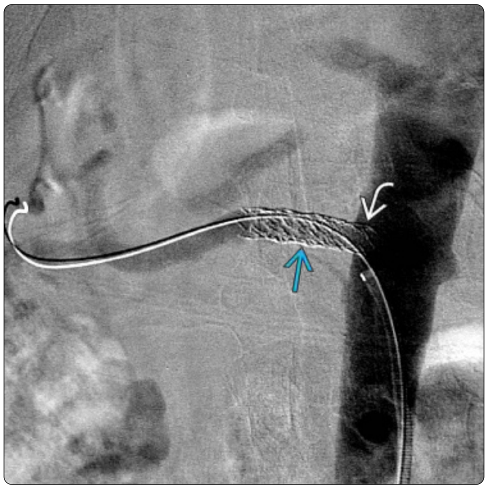
Renal Artery Stent Fracture (Selective Renal Angiogram Through Sheath)



Renal Artery Stent Fracture (Post 1st Stent Placement Angiogram)

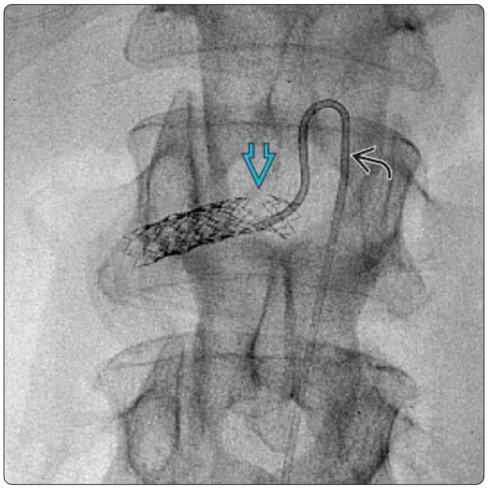


Renal Artery Stent Fracture (Final Angiogram)

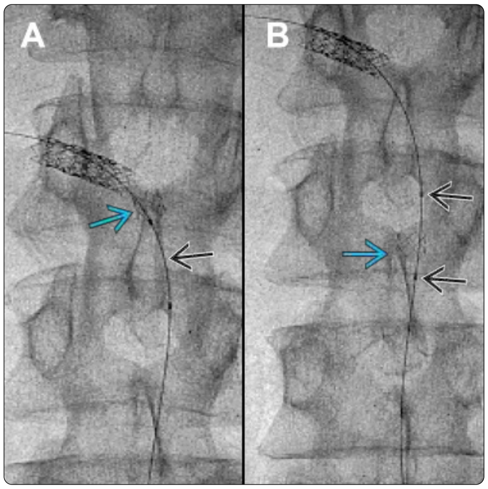


(Left) *A 6x15-mm PalMaz Blue balloon expandable stent → was chosen. After deployment, the image intensifier obliquity was changed. This showed the stent did not extend into the aortic lumen or cover the ostial stenosis ➡ as it had appeared to on the AP projection. Note the stub of the origin of the occluded left renal artery ↪.* **(Right)** *This malpositioning of the stent necessitated repeat stent placement →. Now the central portion of the stent projects into the aortic lumen by 1-2 mm ↪. There was no residual pressure gradient.*

Renal Artery Stent Fracture (Follow-Up Angiogram)

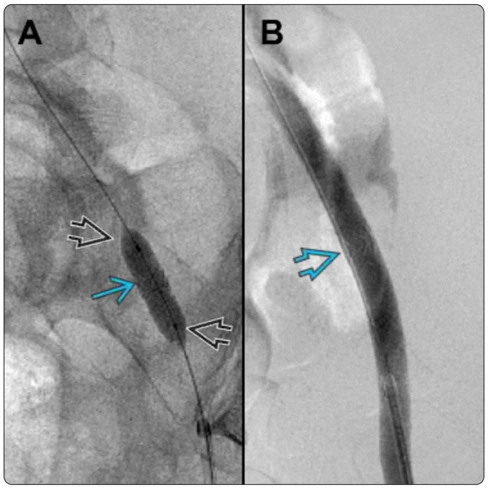


Renal Artery Stent Fracture (Treatment of Fractured Stent)

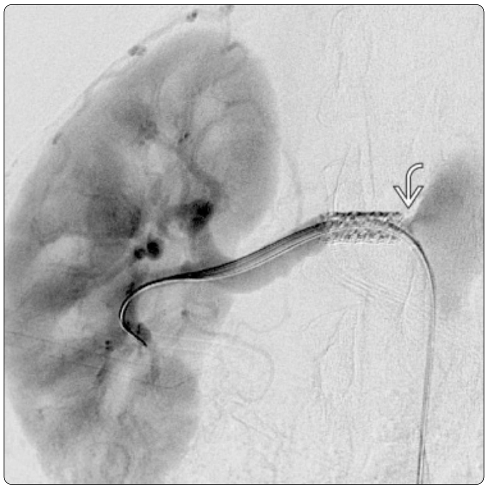


(Left) *Patient's hypertension initially responded but returned 1 week later. Spot radiography at the time of her repeat angiogram showed an unexpected finding, a fracture → of the superior portion of the stent. Note the SOS-2 catheter ↪.* **(Right)** *(A) After wire access was obtained through the stents. A 7-mm balloon → was advanced and, through repeated gentle back and forth movements, the fracture was intentionally completed →. (B) The fracture fragment was pulled down over this partially inflated balloon.*

Renal Artery Stent Fracture (Treatment of Fracture Stent)

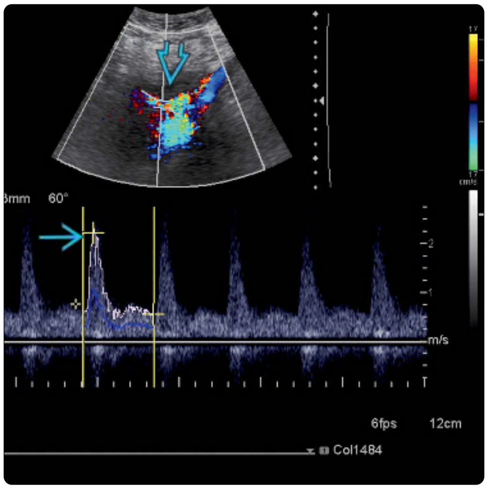


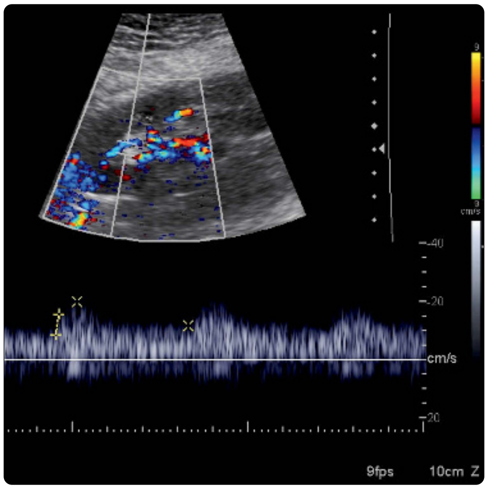
Renal Artery Fracture (Final Renal Angiogram)



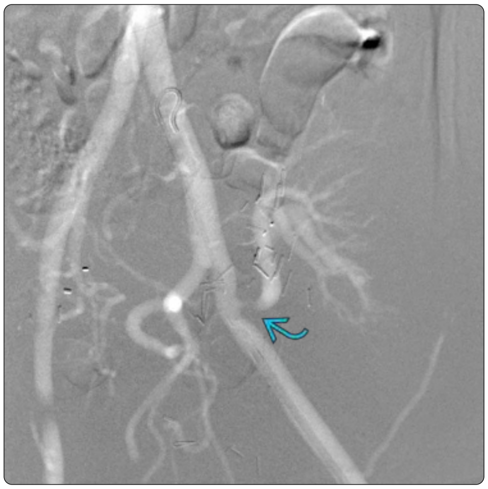
(Left) *(A) The fractured portion of the stent → was then deployed in the left iliac artery, using an 8-mm balloon ⇨. (B) Post deployment DSA showed it to be acceptably positioned ⇨ within the patent iliac artery.* **(Right)** *Final aortogram showed good perfusion to the right kidney. The renal artery orifice ↪ is no longer stented. Pressure measurement across this orifice was 11 mm Hg systolic gradient. No further intervention was performed.*

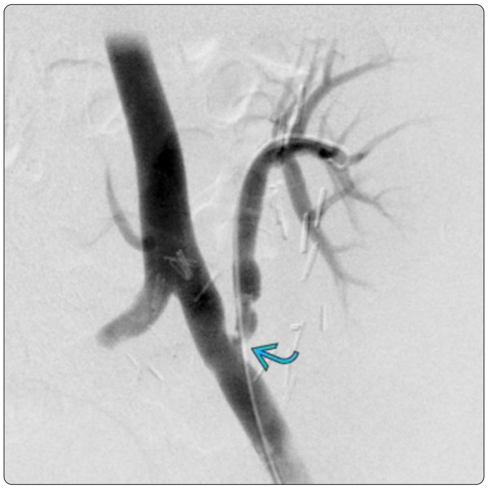
(Left) *A 35-year-old woman with ESRD who is status post renal transplant 6 months prior now with declining eGFR is shown. Markedly elevated peak systolic velocity (240 cm/second) ➙ and aliasing ⇨ at the origin of the transplanted renal artery are consistent with stenosis at the external iliac to transplanted renal artery anastomosis.* **(Right)** *Intrarenal Doppler shows parvus (low amplitude of 20 cm/second) et tardus (late rising/rounded) waveforms consistent with upstream stenosis as seen at the anastomosis.*


Transplant Renal Artery Stenosis

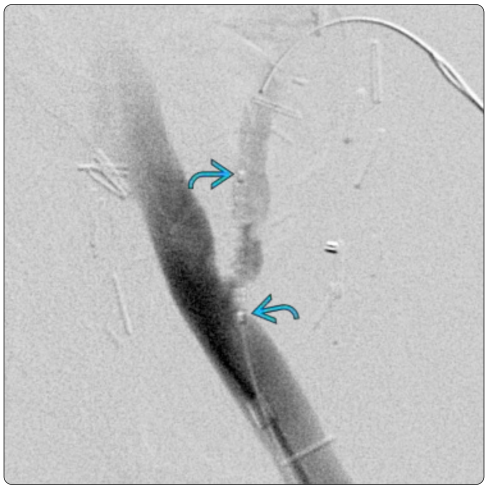

Transplant Renal Artery Stenosis

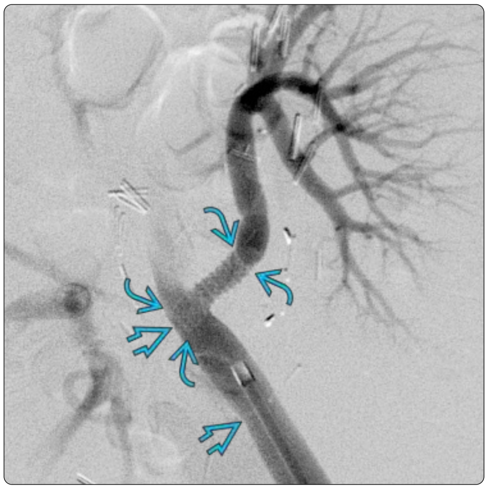
(Left) *Given the worsening renal function, the decision was made to proceed with angiogram and possible intervention. CO_2 was chosen for the initial angiograms to avoid further impairment in renal function. Angiography confirmed severe stenosis at the origin of the transplanted renal artery ⤻. Ipsilateral puncture/approach was chosen.* **(Right)** *The stenosis ⤻ was traversed, and a 0.035" Rosen wire was placed.*


Transplant Renal Artery Stenosis

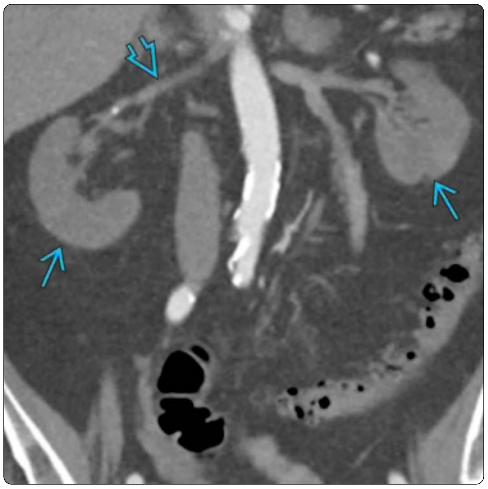

Transplant Renal Artery Stenosis (Stent Migration)

(Left) *Repeat angiogram prior to deployment of the balloon expandable stent ⤻ shows it is positioned well, extending slightly into the external iliac artery beyond the ostium of the renal artery.* **(Right)** *Post deployment angiogram shows the stent ⤻ has migrated proximally with its proximal-most portion on the medial wall of the external iliac artery ⇨. It migrated because it was not properly oversized. This malpositioning precludes subsequent renal artery intervention and places the iliac artery at risk for subsequent stenosis.*

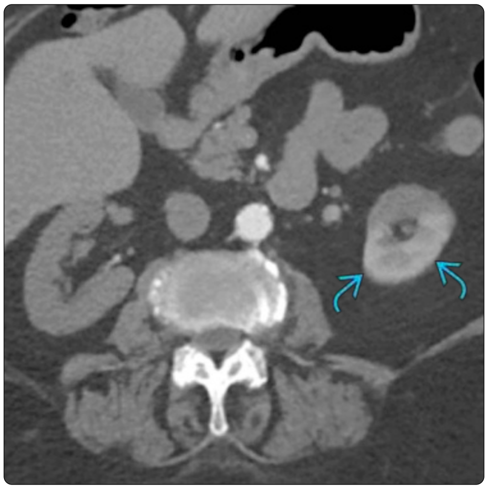

Transplant Renal Artery Stenosis (Stent Migration)


Transplant Renal Artery Stenosis (Stent Migration)

Acute Renal Artery Occlusion (CTA)

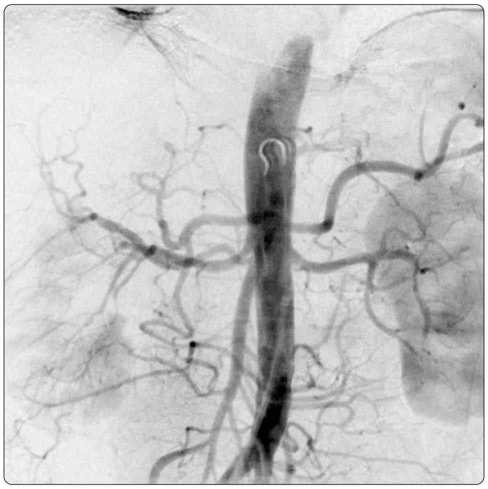


Acute Renal Artery Occlusion (CTA)

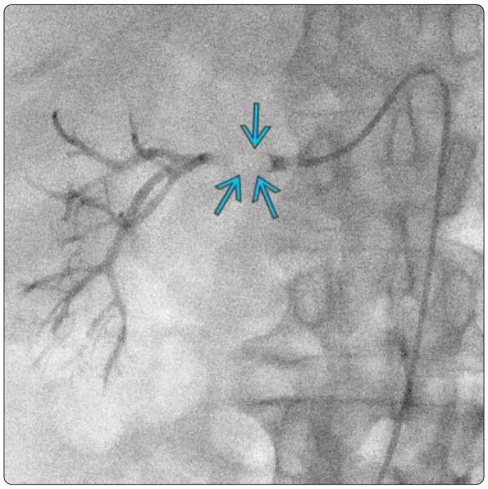


(Left) *CTA shows bilateral renal artery thrombosis ⇨ with poor enhancement of the kidneys → bilaterally.* **(Right)** *Axial CTA shows some patchy perfusion of the posterior lower pole of the left kidney ↪ supplied via a small accessory branch. When considering revascularization of an acutely ischemic kidney, the previously thought 1- to 3-hour window for revascularization is too short, as positive outcomes have been reported with initiation of the procedure up to 19 hours after the ischemic event.*

Acute Renal Artery Occlusion (DSA)

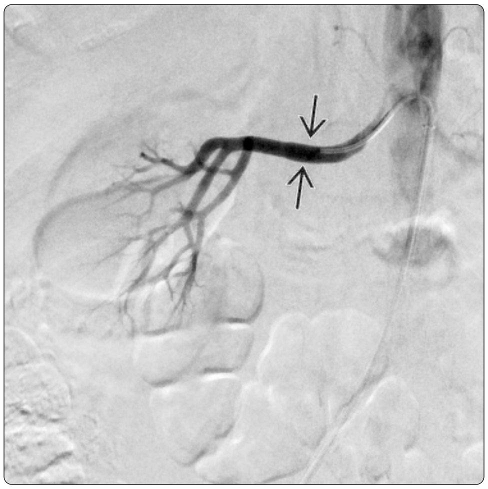


Acute Renal Artery Occlusion (Angiogram)

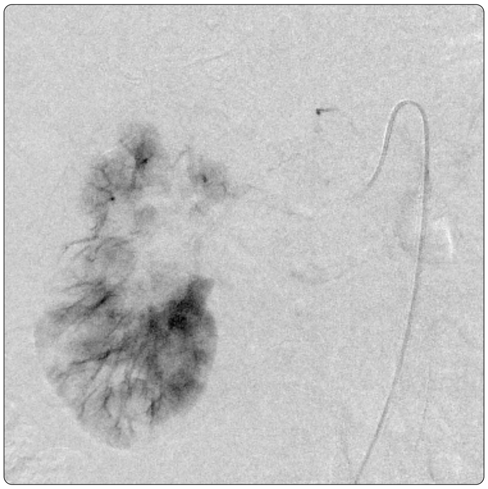


(Left) *After performing thrombectomy on the left kidney (not shown) repeat angiogram showed patency of the left renal artery with normal parenchymal staining. The right renal artery is occluded without a corresponding parenchymal stain.* **(Right)** *The right renal artery was then selected with a Simmons-2 catheter. Angiogram showed occlusion of the mid right renal artery → with a meniscus of contrast at the proximal portion of the clot and focal expansion of the occluded portion of the renal artery.*

Acute Renal Artery Occlusion (Angiogram)



Acute Renal Artery Occlusion (Angiogram)



(Left) *After giving a bolus of tPA followed by continuous infusion over 1 hour, repeat angiogram showed a patent right renal artery →. No underlying stenosis was seen.* **(Right)** *Delayed image from that angiogram showed spotty parenchymal perfusion, likely from fragmentation and more distal embolization of portions of the clot. Patient was placed on a heparin drip and renal function nearly fully recovered.*

KEY FACTS

PREPROCEDURE

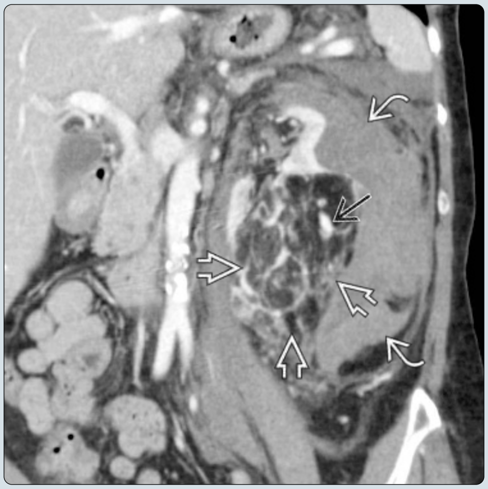
- Renal trauma
  - CT is modality of choice to categorize injury
- Angiomyolipoma (AML): US, MR, and CT can all show fatty components
  - Note: 5% of AML are fat poor

PROCEDURE

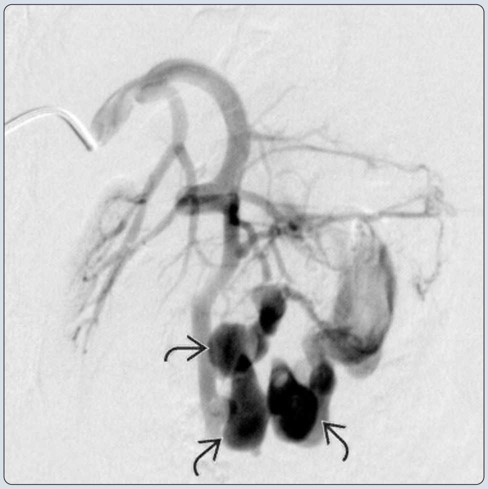
- **Trauma**
  - Conservative management for low-grade injuries
  - Endovascular treatment of intermediate-grade injuries and pseudoaneurysm (PSA)
  - Nephrectomy often necessary for high-grade injuries or hemodynamic instability
- **PSA**
  - Treat with coil embolization or stent graft occlusion
  - If related to percutaneous nephrostomy placement, perform angiogram with percutaneous nephrostomy removed over wire
- **Arteriovenous fistula (AVF)**
  - Assess anatomy of feeding vessels/draining veins
  - Detachable coils preferred
  - Consider Amplatzer plug for large AVF
- **Angiomyolipoma (AML)**
  - Prophylactic treatment for lesion > 4 cm or intratumoral aneurysm > 5 mm
  - Emergency treatment for rupture
  - Perform highly selective embolization to preserve normal renal tissue
  - Multiple varied embolization techniques described agents
    - 70% ethanol with 30% iodized oil (Lipiodol)
    - Particles of varying sizes
    - Gelfoam sandwich with coils
- **Renal artery aneurysm (RAA) exclusion**
  - Branch renal artery
    - Coil embolization, stent assisted coiling or stent graft
  - Main RAA exclusion: Covered stent

(Left) *This patient presenting to the ED with sudden onset of flank pain was diagnosed with a large perinephric hematoma* ➡ *related to a previously undiagnosed sporadic angiomyolipoma (AML)* ➡*. Areas of aneurysmal dilation within the mass are seen* ⇨*.* **(Right)** *Selective left renal DSA shows multiple intratumoral aneurysms* ⇨ *that are characteristic of an AML. Many embolization techniques are described in this chapter. The goal is to devascularize the tumor while preserving adjacent normal renal parenchyma.*

Ruptured AML (Coronal CT)

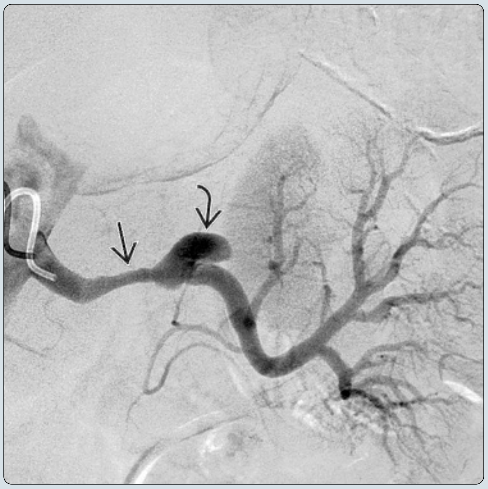


Ruptured AML (Left Renal Angiogram)

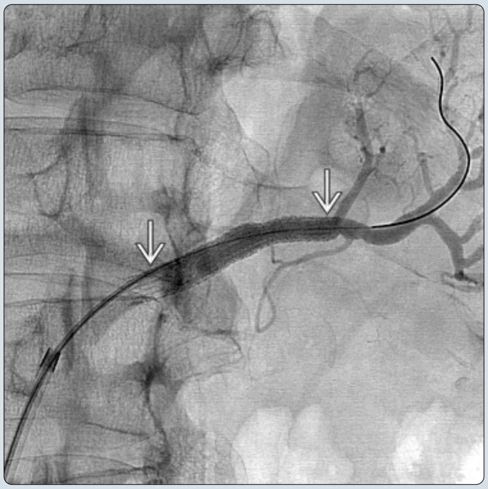


(Left) *A left renal angiogram in a 52-year-old man shows narrowing of the mid left renal artery* ⇨*, possibly related to FMD-associated dissection, and an adjacent oblong-shaped pseudoaneurysm (PSA)* ⇨*.* **(Right)** *After placing a 0.018" guidewire and long sheath into the left renal artery, a 6-mm diameter covered stent (Gore Viabahn)* ➡ *was deployed. Repeat angiogram shows exclusion of the PSA and improvement in the caliber of the renal artery just proximal to this PSA.*

Renal Artery Pseudoaneurysm Exclusion (Initial Angiogram)



Renal Artery Pseudoaneurysm Exclusion (Post Stent Graft)



TERMINOLOGY

Definitions

- **Renal trauma**
  - Blunt, penetrating, or iatrogenic injury
    - Iatrogenic causes of renovascular injury
      - ☐ Biopsy
      - ☐ Percutaneous nephrostomy/nephrolithotomy
      - ☐ Extracorporeal shock wave lithotripsy
  - Hematuria present in 95% of patients with renal trauma
- **Grading of renal trauma**
  - Grade 1
    - Small parenchymal contusion
    - Stable subcapsular hematoma
      - ☐ Treatment: Conservative
  - Grade 2
    - Laceration < 1 cm in depth
    - Stable perirenal hematoma
      - ☐ Treatment: Conservative
  - Grade 3
    - Laceration > 1 cm in depth
      - ☐ No extension into collecting system
      - ☐ Treatment: Conservative if stable, angiogram ± intervention if ongoing blood loss or hemodynamically unstable
  - Grade 4
    - Laceration that extends into collecting system
    - Vascular injury of main renal artery or vein
    - Expanding subcapsular or perinephric hematomas
      - ☐ Treatment: Angiogram and embolization
  - Grade 5
    - Avulsion of renal hilum with devascularization of kidney
    - Complete laceration or thrombosis of main renal artery or vein
    - Ureteropelvic junction avulsion
    - Shattered kidney
      - ☐ Treatment: Varied, nephrectomy often performed
- **Renal artery pseudoaneurysm (PSA)**
  - Focal disruption/rupture of arterial wall
  - Symptoms: Hypertension/flank pain/hematuria
  - Etiologies: Traumatic, spontaneous, iatrogenic, vasculitis (e.g., polyarteritis nodosa)
- **Renal arteriovenous fistula (AVF)**
  - Abnormal connection between artery and vein
    - Causes abnormal hemodynamics (high-output heart failure, shunting away from normal kidney tissue)
  - Symptoms: Hypertension/high-output heart failure/hematuria/renal insufficiency
  - Etiologies
    - Often acquired (posttraumatic/iatrogenic)
- **Angiomyolipoma (AML)**
  - Benign hamartomatous tumors
    - Variable amounts of blood vessels/muscle/fat
  - Abnormal blood vessels
    - No internal elastic lamina, disordered fibrotic smooth muscle cells
    - Prone to intratumoral aneurysm formation and rupture
  - 80% sporadic
    - Typically unilateral; often static/slowly growing
  - 20% associated with tuberous sclerosis complex (TSC)
    - Often bilateral/large; progressive growth
- **Renal arteriovenous malformation (AVM)**
  - Typically congenital
  - Multiple communications between arteries and veins
- **Renal artery aneurysm (RAA)**
  - 2nd most common visceral aneurysm (15-22%) after splenic
  - Congenital causes: Fibromuscular dysplasia, phakomatoses (e.g., tuberous sclerosis, neurofibromatosis), intrinsic collagen deficiencies (e.g., Ehlers-Danlos, Marfan), vasculitides (e.g., Behcet)
  - Acquired causes: Atherosclerosis/degenerative
  - Often asymptomatic
  - Possible symptoms
    - Hypertension/renal insufficiency from microemboli
    - Hematuria/flank pain from aneurysm rupture
  - Tend to occur at bifurcation of main renal artery
- **Renal artery perforation/rupture**
  - Occurs in 3.5% of renal artery interventions

PREPROCEDURE

Indications

- **Grades III and IV trauma usually managed endovascularly**
- **PSA**
  - Intervention necessary regardless of size
    - High potential for rupture
- **AVF/AVM**
  - Treat if symptomatic (congestive heart failure, renal insufficiency, hematuria)
- **AML treatment**
  - Prophylactic treatment
    - > 4 cm in diameter
    - Intratumoral aneurysms > 5 mm
  - Emergent treatment
    - Acute rupture/hemorrhage
- **RAA exclusion**
  - Aneurysm size > 1.5 cm
  - Increasing aneurysm size
  - Pregnancy or planned future pregnancy
- **Complete renal occlusion**
  - **Nonfunctioning kidneys**
    - Poor nephrectomy candidate with
      - ☐ Severe nephrotic syndrome
      - ☐ Uncontrollable hypertension
      - ☐ Hydronephrosis with pain
      - ☐ Polycystic kidney disease
  - **Preoperative embolization for renal cell carcinoma**
    - No longer routinely performed
    - Can be performed on individual basis
      - ☐ e.g., minimize blood loss in Jehovah's Witness
  - **Palliative treatment of renal cell carcinoma**
    - Poor nephrectomy candidate but symptomatic
      - ☐ e.g., hematuria, paraneoplastic syndrome

Preprocedure Imaging

- **Trauma**: Best evaluated by computed tomography (CTA/CECT)

- **PSA, RAA, AVF, AVM**
  - CTA/MRA depicts vascular anatomy
  - May be detected by color Doppler US
- **AML**
  - Fatty components
    - Ultrasound: Hyperechoic mass
    - CT: Look for fat density (-30 to -100 HU)
    - MR: Increased precontrast T1 signal and signal drop out on fat-saturation images
  - 5% of AMLs are fat poor
  - Bizarre vasculature and intratumoral aneurysms may be identified

Getting Started

- Things to check
  - Labs
    - Serum creatinine, eGFR
      - ☐ Note often done in setting of renal insufficiency
    - Platelets, coagulation parameters
      - ☐ Prefer platelets > 50,000 μL; INR ≤ 1.8
  - Allergies
- Equipment list
  - Embolization materials
    - Includes liquid embolic (ethanol), glue (N-butyl cyanoacrylate), Onyx, Gelfoam, particles (Embosphere or PVA), coils (prefer detachable given precision of deployment), Amplatzer vascular plug for large AVF
    - Embolic used is dependent on embolization being performed, angiographic appearance, and operator preference
  - Coaxial catheters
    - 5-Fr Cobra or reverse curve catheter (e.g., Sos-1, Sos-2, Simmons-1, Simmons-2); microcatheter
    - 6-Fr guiding catheter (e.g., RDC) or 6-Fr sheath (Ansel)
      - ☐ Coaxial 5-Fr catheter; microcatheter
    - 4- to 5-Fr guiding catheter; coaxial microcatheter

PROCEDURE

Procedure Steps

- Vary widely depending on lesion/indication
- **General**
  - Obtain femoral arterial access
    - Radial access possible alternative: Based on operator preference and renal artery anatomy
  - Perform aortogram
    - Useful for depicting accessory renal arteries
    - Tumors may recruit from surrounding vessels
      - ☐ e.g., adrenal, gonadal, lumbar arteries
  - Selectively catheterize main renal artery
    - 5-Fr Cobra or reverse curve catheter (Sos-1, Sos-2, Simmons-1, Simmons-2)
  - Perform renal artery angiogram
    - Assess renal vascular anatomy, lesion location
  - Subselect renal artery branches with microcatheter as needed to optimize intervention
  - Choose embolic agent/technique based on
    - Lesion characteristics/accessibility/anatomy
  - Perform embolization
  - Obtain postprocedure angiogram from main renal/aorta
    - Evaluate adequacy of treatment/embolization
    - Determine degree of renal parenchymal loss
    - Assess for any complications
- **PSA**
  - Selectively catheterize affected branch
  - If due to iatrogenic trauma from nephrostomy tube, remove tube over guidewire during angiogram
    - Tamponade effect from tube may obscure arterial injury
  - Embolize with microcoils
    - Deploy microcoils starting distal to, within, and then proximal to PSA if possible
- **AVF/AVM**
  - Assess anatomy of feeding vessels/draining veins
    - Number, size, location of feeding arteries
    - Best access to nidus
    - Flow rate through draining vein(s)
  - AVM
    - Goal of AVM treatment: Eradicate nidus of communication between arteries and veins
      - ☐ Treatment of feeding arteries without embolizing nidus will result in incomplete treatment, which will be more challenging to treat when AVM returns
    - Perform DSA from feeding arteries to ascertain flow rate, flow volume
    - Look for shunting, which can result in embolics passing through AVM to venous system
    - Consider occlusion balloon prior to deploying embolics
    - Advance microcatheter to/into nidus
    - Can use various embolic agents
      - ☐ Ethanol, N-butyl cyanoacrylate, Onyx, particles, coils
      - ☐ Liquid embolics best in complex AVM
  - Simple AVF
    - Single feeding artery and vein
    - Coil embolization of feeding artery typically possible and successful
  - Small/moderate AVF
    - 1st create framework using large detachable coil
      - ☐ Detachable coils can be retrieved if stable coil position not achieved
    - Place additional smaller coils inside framework
  - Larger AVF
    - Seal venous side with balloon occlusion catheter before embolization
    - Consider Amplatz plug occluder given high risk of venous coil migration
- **AML**
  - Evaluate number, diameter of tortuous irregular feeding/intratumoral vessels
    - Access dominant feeding vessel(s)
    - Embolize as selectively as possible
    - Avoid noninvolved renal parenchyma
  - Base embolization technique on lesion anatomy
    - Endpoint: Stasis within target circulation
  - Possible embolization agents
    - 70% ethanol with 30% iodized oil (Lipiodol)
    - Particulate embolization
    - Avoid using coils (do not travel distal into AML)
- **RAA exclusion**
  - Branch renal artery

Renal Injury Grading Scale

	Description	Treatment
Grade 1	Small contusion ± stable subcapsular hematoma	Conservative management
Grade 2	Superficial laceration < 1-cm depth ± stable perirenal haematoma	Conservative management
Grade 3	Laceration > 1 cm without extension into collecting system	Conservative management if stable angiogram ± endovascular intervention if ongoing bleeding or hemodynamic instability
Grade 4	Laceration which involves urinary collecting system; vascular injury to main renal artery or vein; expanding subcapsular haematomas compressing kidney	Angiogram ± endovascular intervention
Grade 5	Shattered kidney; avulsion of renal hilum with devascularization of a kidney; ureteropelvic avulsion; complete laceration or thrombosis of the main renal artery or vein	Ureteric stent across the injury site or percutaneous nephrostomy for urinary diversion for ureteropelvic junction avulsion; nephrectomy should be considered

Dayal M et al. Imaging in renal trauma. World J Radiol. 5(8): 275-284. 2013

    - Coil embolization (narrow-neck RAA)
    - Stent-assisted coiling (wide-neck RAA)
    - Stent graft placement (challenging if vessel tortuous)
  - Main renal artery
    - Treat with stent graft
- **Iatrogenic renal artery perforation**
  - Proximal renal artery perforation
    - Covered stent placement
  - Distal renal branch perforation
    - Treat with coil embolization
- **Total renal artery occlusion**
  - Embolization with 95% ethanol
    - Selectively catheterize renal artery
    - Inflate occlusion balloon in main renal artery
    - Inject 10- to 15-mL ethanol; wait 10 minutes
    - Inject contrast; see if artery occluded/thrombosed
    - Repeat if still patent; limit ethanol dose to 50 mL
  - Particle embolization

Alternative Procedures/Therapies

- Surgical
  - Trauma
    - Nephrectomy often necessary in high-grade trauma
  - Aneurysm/PSA repair/resection
    - Difficult, often morbid surgery
    - High rate of nephrectomy needed
  - AML
    - Nephrectomy or partial nephrectomy
      - Greater parenchymal loss; longer recovery time
- Other
  - Medical management
    - Sirolimus for AML
      - Inactivates target of rapamycin complex, which is dysregulated in TSC

OUTCOMES

Complications

- Most feared complication(s)
  - Periprocedural aneurysm rupture in AML
  - Venous migration of coils through large AVF
- Immediate/periprocedural complication(s)
  - Arterial injury (e.g., dissection/thrombosis)
  - Nontarget embolization/excessive parenchymal loss
    - If superselective embolization not performed
- Delayed complication(s)
  - Decline in eGFR may occur due to
    - Contrast nephrotoxicity
    - Nontarget renal parenchymal loss
  - Renal abscess formation
  - AML recurrence (15-37%)
    - Most often in TSC patients
    - Repeat embolization may be necessary (23%)
- Other complications
  - Postembolization syndrome (AML embolization)
    - Inflammatory response to necrotic tissue
    - Affects 90% of AML embolization patients
      - Symptoms: Pain, nausea, vomiting, fever
      - Treat with IV fluids, analgesics, antipyretics, antiemetics, tapered dose of prednisone
    - Tumor necrosis may cause lipiduria
  - Arterial access complications

Expected Outcomes

- Preservation of unaffected renal parenchyma
- Technical success
  - Trauma: Occlusion of bleeding source
  - RAA/PSA/AVF/AVM: Successful exclusion/elimination
  - AML
    - Tumor volume decreases by 40-66%
      - Fatty component relatively insensitive to embolization
    - Recurrence rate up to 37% (43% in tuberous sclerosis)

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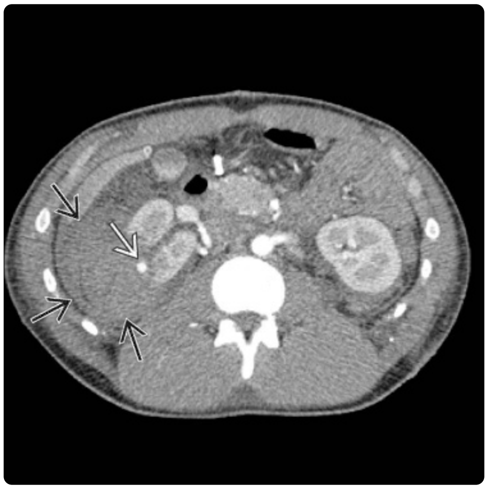
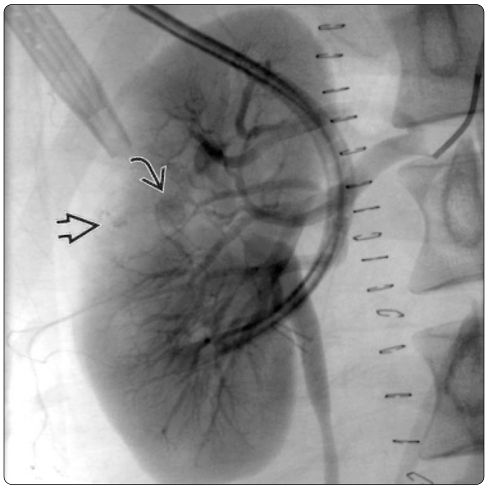
1. Hellmund A et al: Rupture of renal artery aneurysm during late pregnancy: clinical features and diagnosis. Arch Gynecol Obstet. 293(3):505-8, 2016
2. Ramaswamy RS et al: Arterial embolization for the treatment of renal masses and traumatic renal injuries. Tech Vasc Interv Radiol. 19(3):203-10, 2016
3. Coleman DM et al: Renal artery aneurysms. J Vasc Surg. 62(3):779-85, 2015
4. Kautza B et al: "Management of blunt renal injury: what is new?". Eur J Trauma Emerg Surg. 41(3):251-8, 2015

(Left) *A 20-year-old man sustained multiple gun shot wounds and was brought immediately to the OR for exploratory laparotomy. Continuous transfusion requirements following repair of bowel and liver lacerations prompted this CECT. A large perinephric hematoma* → *is seen and a PSA* ⇨ *is present.* **(Right)** *Late arterial images show contrast pooling in the PSA* ↷*, as demonstrated on the CT. Additionally, a small area of extravasation* ⇨ *is seen just lateral to the PSA.*

Penetrating Renal Trauma (Initial CT)

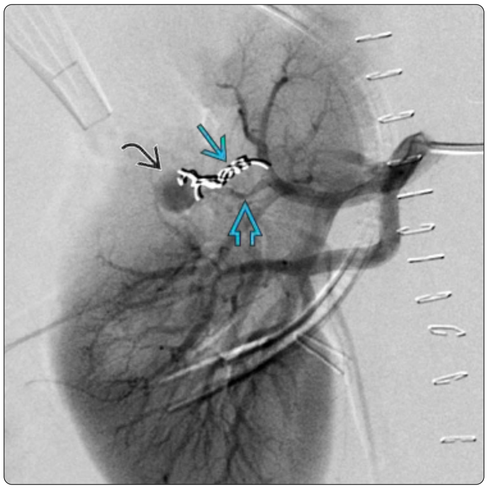


Penetrating Renal Trauma (Initial Angiogram Delayed)

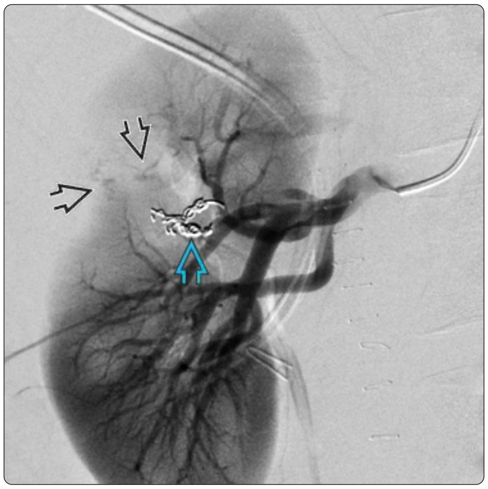


(Left) *The distal branch artery responsible for the lateral contrast extravasation was selected and embolized* →*. A postembolization arteriogram shows that the lateral bleed has stopped, while the mid/upper pole PSA* ↷ *is still present, fed by a more inferior branch* ⇨*.* **(Right)** *The more inferior branch was selected with a microcatheter and embolized with microcoils* ⇨*. While the PSA no longer opacifies, areas of persistent contrast extravasation are present* ⇨*.*

Penetrating Renal Trauma (1st Embolization)

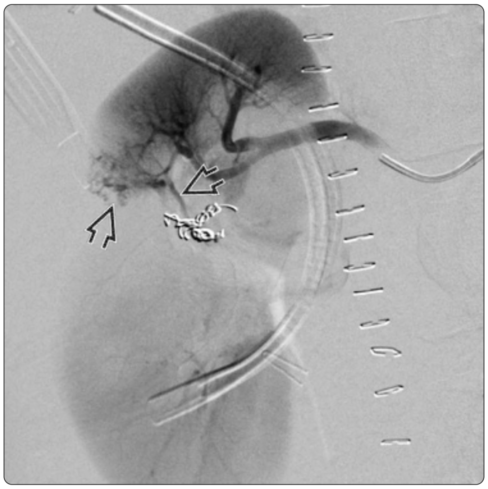


Penetrating Renal Trauma (2nd Embolization)

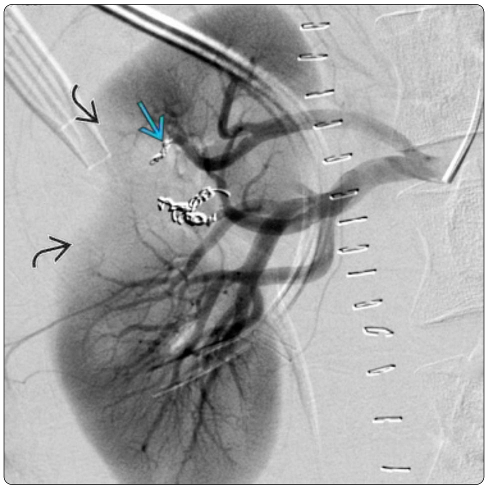


(Left) *The Simmons-1 catheter was positioned into the upper pole renal artery branch, and repeat contrast injection was performed showing extravasation* ⇨ *at the site of laceration.* **(Right)** *An interlobar artery found to be the source of continued extravasation was embolized with a combination of particles and coils* ⇨*. Final angiography from the main renal artery confirmed resolution of the PSA and 2 sites of extravasation. Embolization caused infarction* ↷ *of ~ 25% of the kidney tissue.*

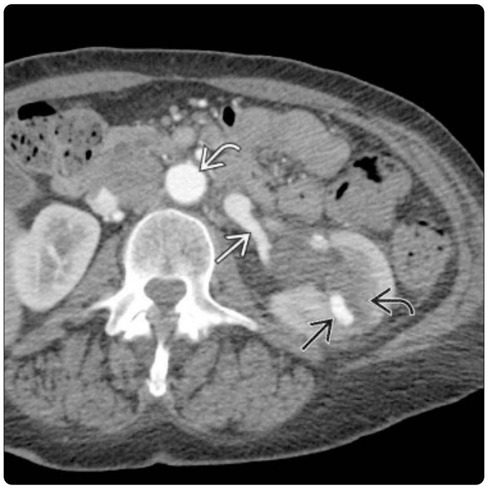
Penetrating Renal Trauma (Selective Upper Pole Angiogram)



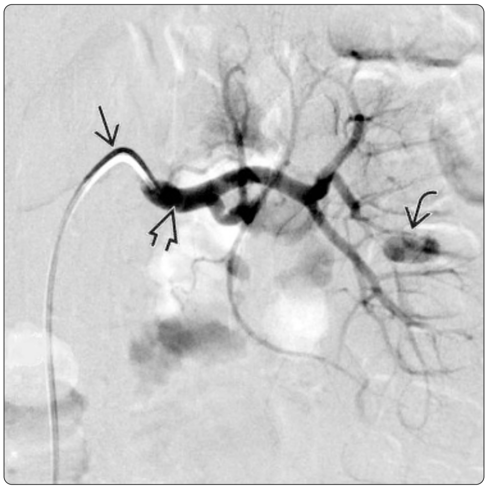
Penetrating Renal Trauma (Final Angiogram)



Blunt Renal Trauma (Initial CT)

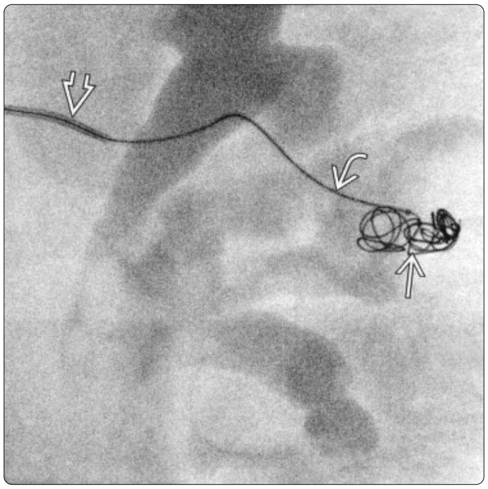


Blunt Renal Trauma (Left Renal DSA)

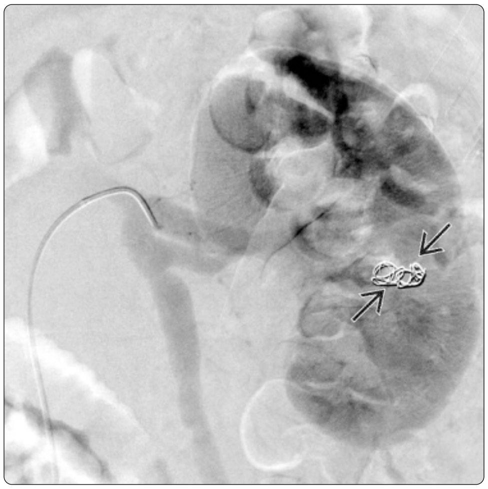


(Left) *CECT in a patient with onset of gross hematuria and flank pain after falling onto her left side shows a contrast collection ⇨ in the renal parenchyma, which simultaneously enhances with the renal artery ➡ and the aorta ↪. A nonenhanced area of renal parenchyma is due to an adjacent renal laceration ↪.* **(Right)** *Selective left renal DSA with Cobra catheter ⇨ positioned in the main renal artery ⇨ is shown. An ovoid contrast collection ⇨ that corresponds to the CECT abnormality is consistent with an arterial PSA.*

Blunt Renal Trauma (Coil Deployment)

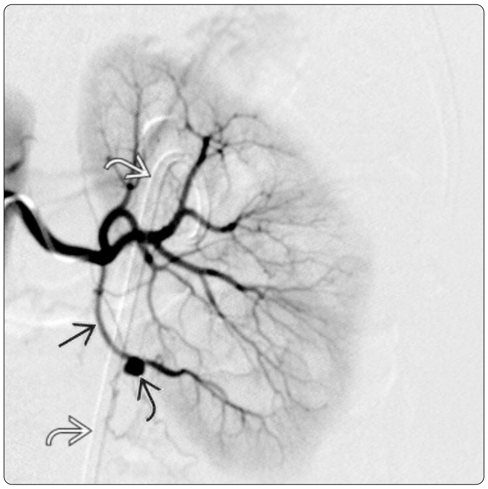


Blunt Renal Trauma (Angiogram After Embolization)

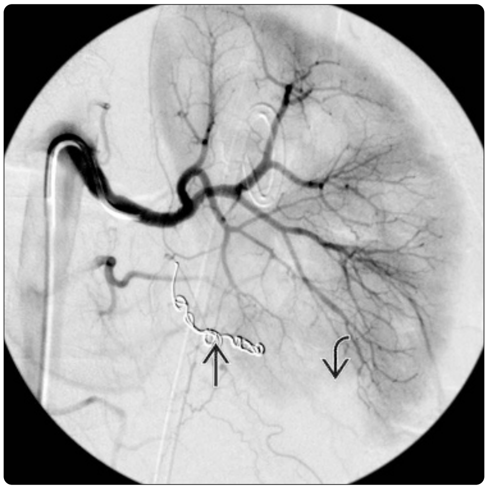


(Left) *Spot radiograph shows that a microcatheter ➡ has been coaxially introduced via the Cobra catheter ➡. The microcatheter tip is positioned in the PSA, and embolization coils ➡ have been introduced into the PSA.* **(Right)** *Parenchymal phase after embolization shows coils ⇨ in place. There is no PSA opacification and no renal parenchymal loss. Untreated PSAs, even when small in size have a high potential for frank rupture.*

Pseudoaneurysm After Endopyelotomy (Renal Arteriogram)



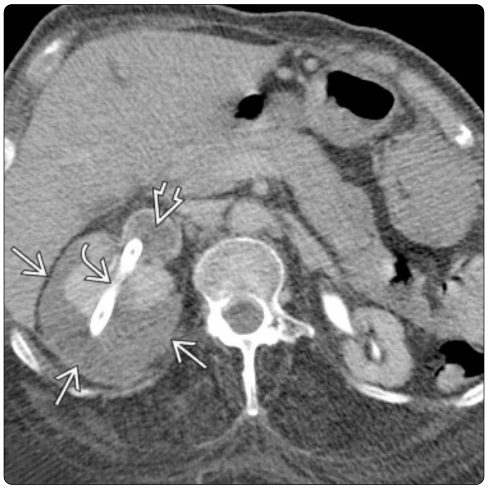
Pseudoaneurysm After Endopyelotomy (Angiogram After Embolization)



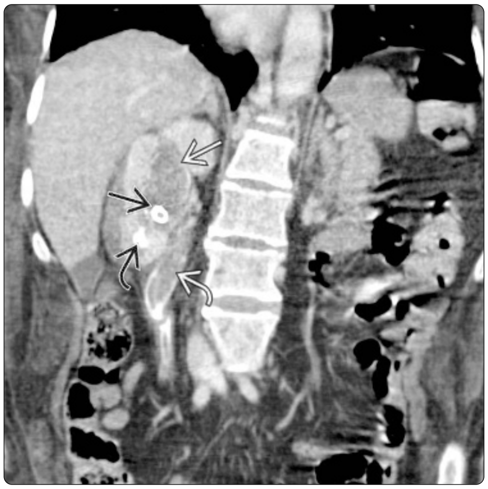
(Left) *This patient developed gross hematuria following an endopyelotomy for ureteropelvic junction obstruction. Left renal artery angiogram shows a PSA ↪ arising from an inferior segmental artery ⇨. Double J ureteral stent is present ➡.* **(Right)** *The PSA was successfully excluded with coil embolization ⇨. A wedge-shaped defect ⇨ in the renal parenchyma, distal to the embolized vessel, is consistent with a small infarct. More selective embolization would have preferred.*

(Left) *After nephrostomy tube placement, this patient became hypotensive and had bright red blood from the nephrostomy tube. Axial CECT shows a right nephrostomy tube ↪ entering a dilated renal pelvis ⇨. A subcapsular hematoma → is present.* **(Right)** *Coronal CT reformation shows the nephrostomy catheter → and combined hydronephrosis → and hydroureter ↪. A focal lower pole contrast collection ↪ is suspicious for a PSA as the cause of bleeding.*

Iatrogenic Arterial Injury (Initial CT, Axial)

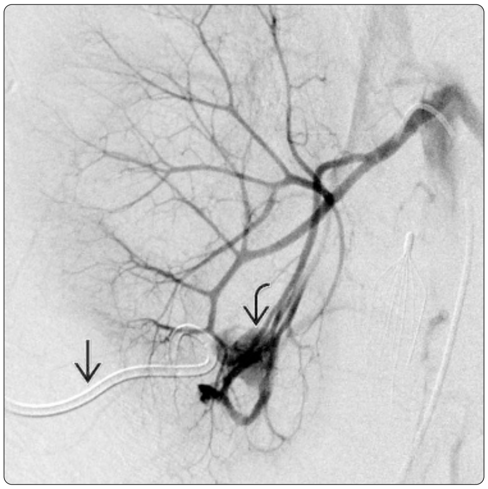


Iatrogenic Arterial Injury (Initial CT, Coronal)

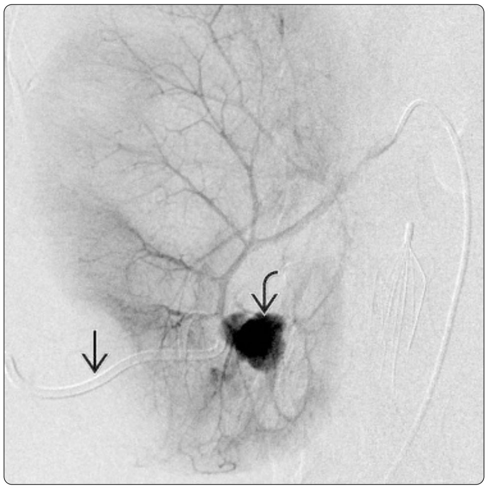


(Left) *The patient developed large-volume hematuria and hypotension after PCN placement. An emergent renal angiogram performed to evaluate the source of bleeding shows a large PSA ↪ next to the recently placed nephrostomy tube →.* **(Right)** *Contrast pools within the PSA ↪ are shown. If a suspected vascular injury from a nephrostomy tube → is not visualized, the angiogram should be repeated with the tube removed over a wire to decrease the tamponade effect.*

Iatrogenic Arterial Injury (Renal Angiogram, Arterial Phase)

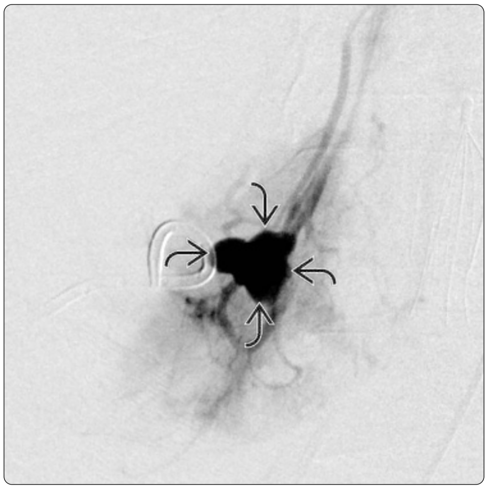


Iatrogenic Arterial Injury (Renal Angiogram, Delayed Phase)

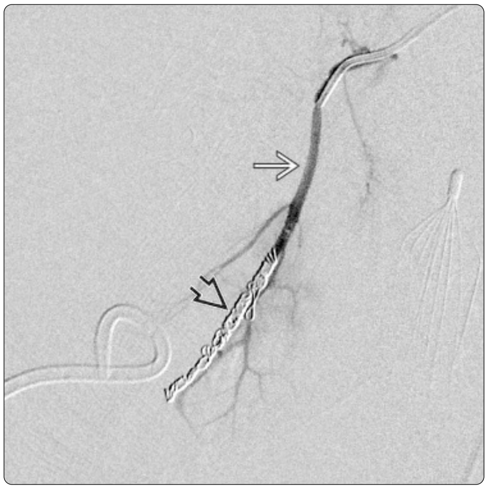


(Left) *More selective injection of a lower pole segmental artery was performed again showing this large multilobulated PSA ↪ adjacent to the nephrostomy tube.* **(Right)** *Placement of multiple coils ⇨ in the injured segmental renal artery → led to exclusion of the PSA. Significant vessel injury occurs in ~ 0.5% of patients undergoing PCN placement.*

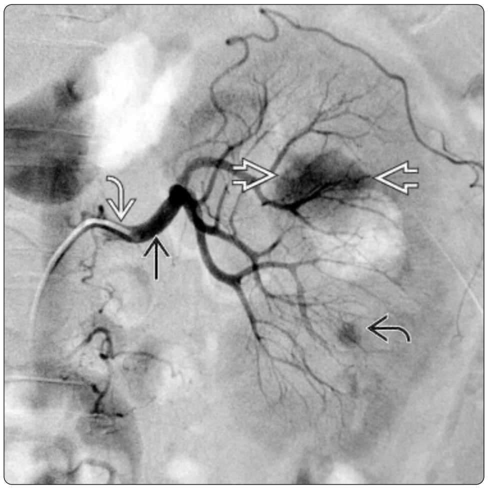
Iatrogenic Arterial Injury (Selective Angiogram)



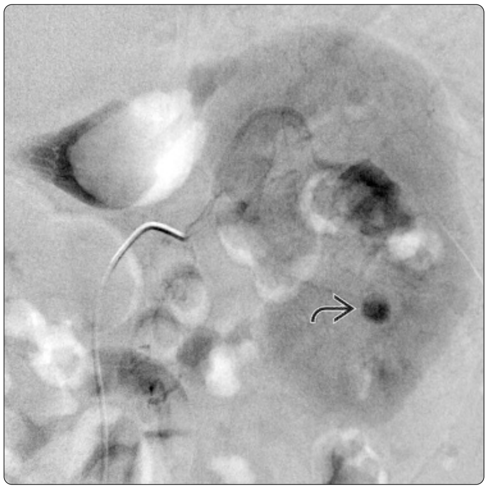
Iatrogenic Arterial Injury (Angiogram After Coil Embolization)



Pseudoaneurysm After Biopsy (Initial Angiogram)

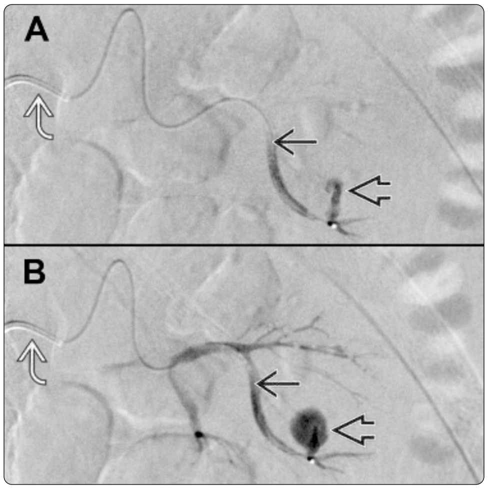


Pseudoaneurysm After Biopsy (Initial Angiogram)

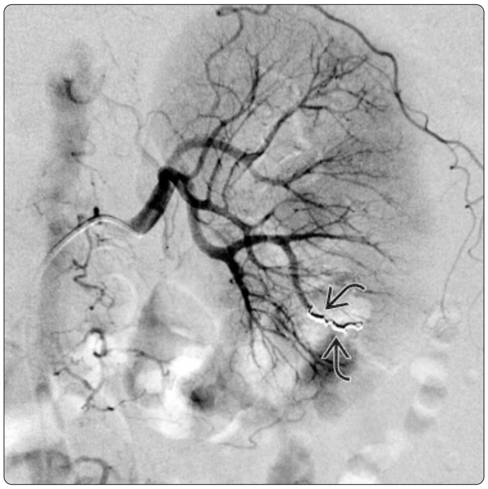


(Left) *Initial DSA via a catheter* ⤷ *in the left main renal artery* → *showed a small left lower pole PSA* ↪. *More superiorly, there is bowel artifact* ➩. **(Right)** *Delayed images show contrast pooling within this PSA* ↪. *Hemorrhagic complications of kidney tissue biopsy occur in ~ 3% of cases.*

Pseudoaneurysm After Biopsy (Selective Angiogram)

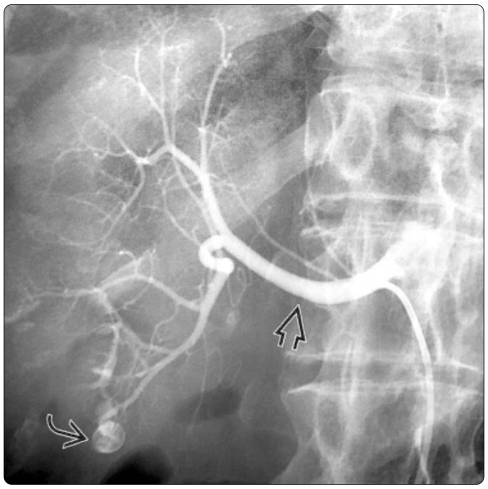


Pseudoaneurysm After Biopsy (Angiogram After Coil Embolization)

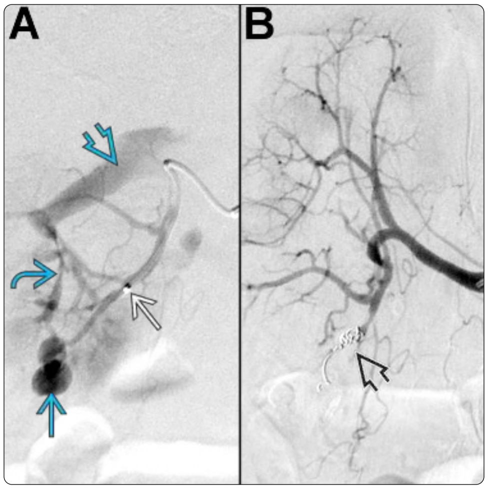


(Left) *A microwire and microcatheter* → *were passed coaxially through the Cobra catheter* ⤷ *selecting the segmental lower pole artery supplying the PSA. Sequential frames from a DSA run show contrast jetting into the PSA* ⇨. **(Right)** *Three coils* ↪ *were placed with successful occlusion of the PSA and minimal normal parenchymal loss. As renal arteries are end arteries, embolizing distal to, at, and proximal to a PSA is not required.*

Combined AVF and PSA After Kidney Biopsy (Initial Angiogram)

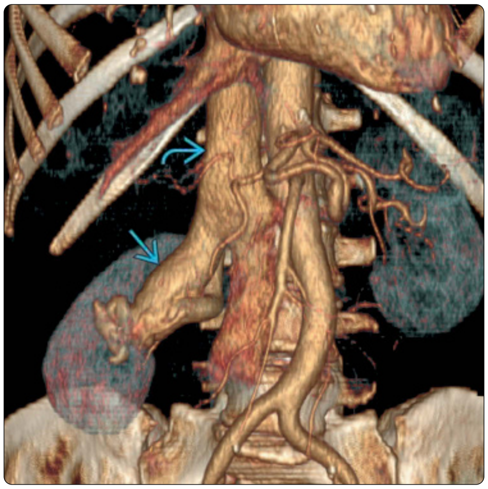


Combined AVF and PSA After Kidney Biopsy (Selective Angiogram and Coiling)

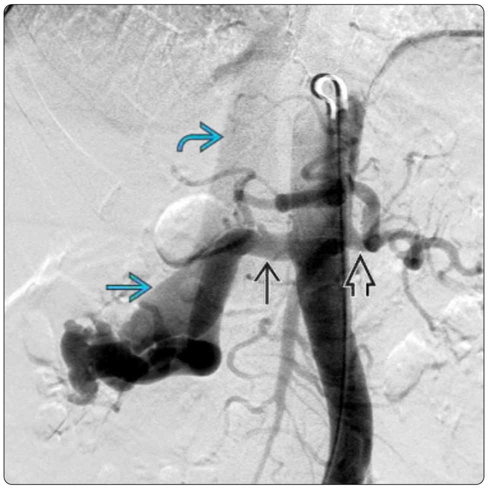


(Left) *A selective right renal artery* ⇨ *angiogram confirms a PSA* ↪ *in the lower renal pole. The diminutive caliber of the intrarenal arteries is from vasoconstriction in response to hypotension.* **(Right)** *A patient became hypotensive following percutaneous biopsy of the right kidney inferior pole. (A) DSA of the inferior renal pole via a coaxial microcatheter* ⇒ *shows an early draining vein* ⇨, *supplied by an AVF* ↪ *arising from a PSA* →. *(B) After coil embolization of the PSA* ⇨, *the PSA and AVF have been excluded.*

(Left) *This 69-year-old woman had increasing dyspnea on exertion, and fatigue. She was found to have a large AVF on a CT done as part of her work-up for high-output congestive heart failure. In arterial phase, there is early filling and marked enlargement of her right renal vein* → *and inferior vena cava (IVC)* ↗*.* **(Right)** *The aortogram shows an enlarged right renal artery* ⇨ *compared to the left* ⇨*. There is brisk early filling of the right renal vein* → *and IVC* ↗*.*

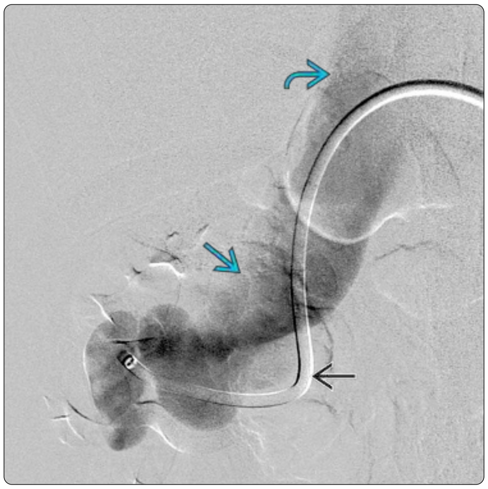


Renal Arteriovenous Fistula (Preprocedure CT)

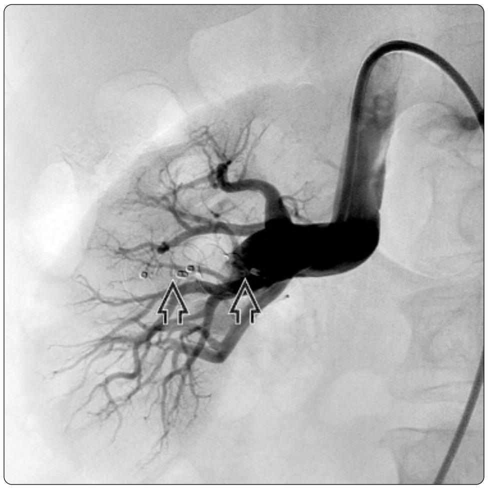


Renal Arteriovenous Fistula (Aortogram)

(Left) *A 6-Fr sheath* → *was advanced to the site of fistulous connection between the right renal artery and right renal vein. Injection showed direct connection with opacification of the enlarged right renal vein* → *and IVC* ↗*.* **(Right)** *Two 16-mm Amplatzer vascular plugs* ⇨ *were deployed at the site of the fistula. Repeat angiogram then showed no opacification of the AVF and no early draining vein. Improved perfusion of the normal renal parenchyma was seen; less blood was being shunted through the AVF.*

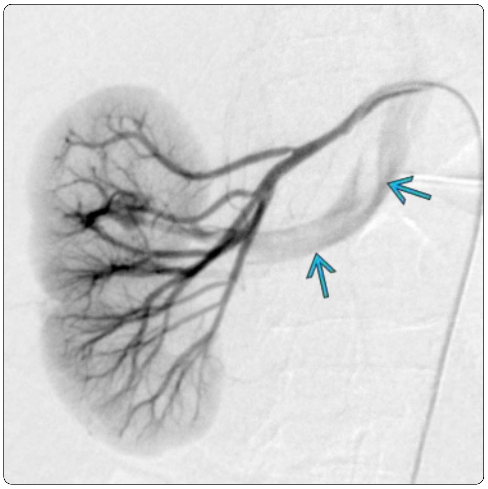


Renal Arteriovenous Fistula (Selective Angiogram)

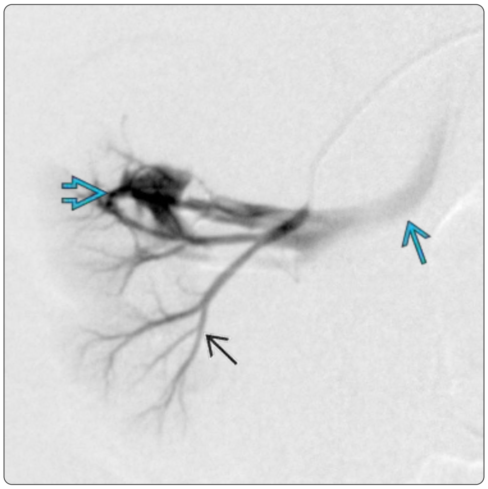


Renal Arteriovenous Fistula (Amplatzer Embolization)

(Left) *A patient developed gross hematuria and hypotension after percutaneous biopsy. Following transfusion of 4 units PRBC and initiation of pressors, this patient was taken for emergent IR intervention. A selective right renal arteriogram shows early venous drainage* → *consistent with AVF.* **(Right)** *A super-selective angiogram again shows the early draining vein* →*, which opacifies simultaneous to the arteries* →*, and the abnormal filling of the AVF* ⇨*.*

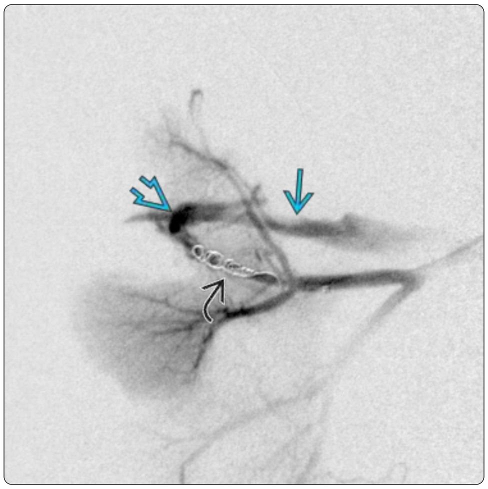


AV Fistula Post Biopsy (Initial Angiogram)

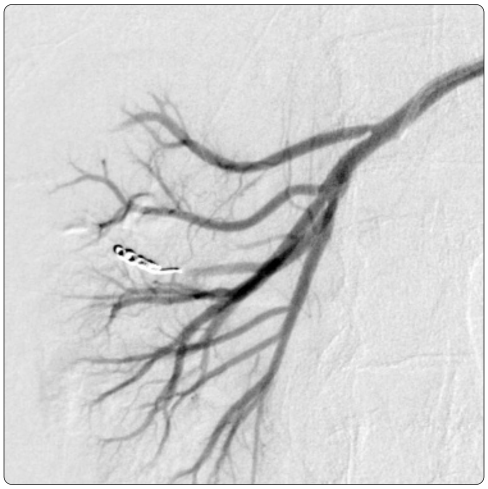


AVF Post Biopsy (Selective Angiogram)

AVF Post Biopsy (Angiogram After Initial Coil Embolization)

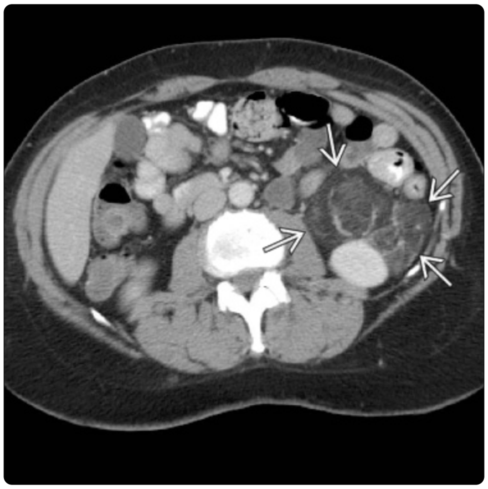


AVF Post Biopsy (Angiogram After Additional Coil Embolization)

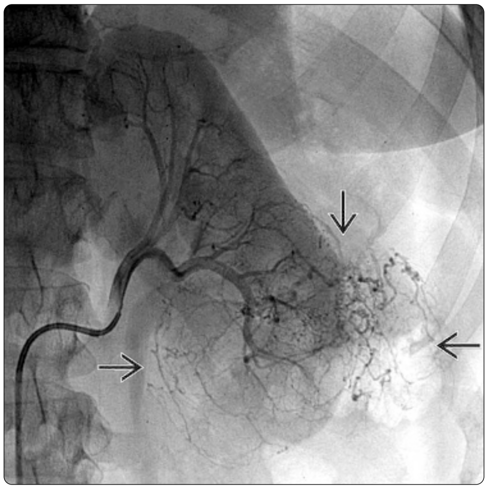


(Left) *The AVF persisted after selective coil embolization* ↪ *of the segmental renal artery. The arteriovenous connection* ⇨ *as well as the early draining vein* → *are still seen. Careful evaluation of the coils reveals that they are not tightly packet together.* **(Right)** *By deploying 1 additional coil into the coil nest, tighter packing was achieved, successfully occluding the vessel feeding the AVF. The early draining vein is no longer seen. The patient's hemodynamics stabilized after embolization.*

Alcohol Embolization of AML (Diagnostic CECT)

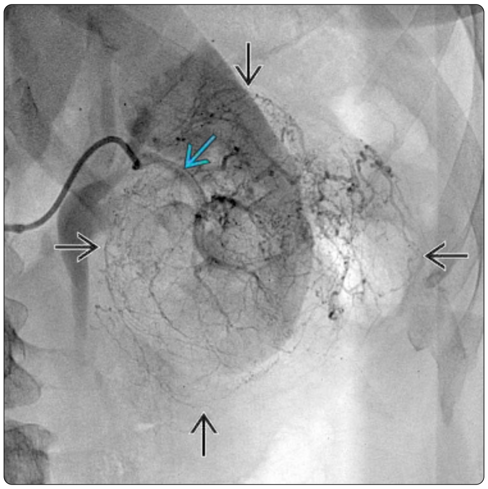


Alcohol Embolization of AML (Initial Angiogram)

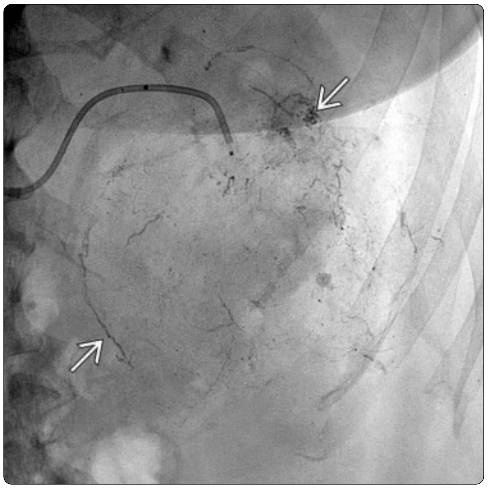


(Left) *A 55-year-old woman with an incidental 8.8-cm exophytic AML* ➡ *is shown. Prophylactic embolization to prevent spontaneous rupture was indicated.* **(Right)** *Initial left renal artery angiogram shows the large exophytic AML* ⇨ *involving the inferior renal pole. The mass is hypervascular with characteristic bizarre tumor vascularity.*

Alcohol Embolization of AML (Selective Angiogram)



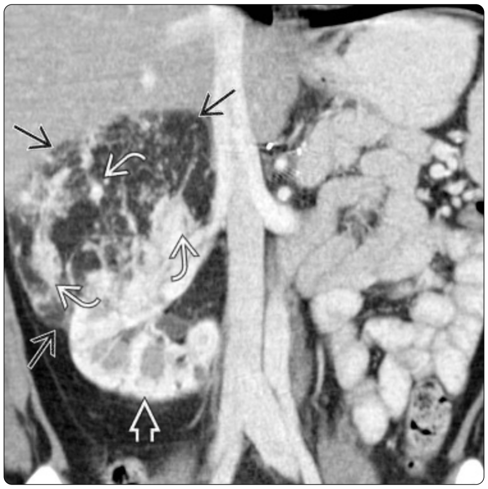
Alcohol Embolization of AML (Postembolization)



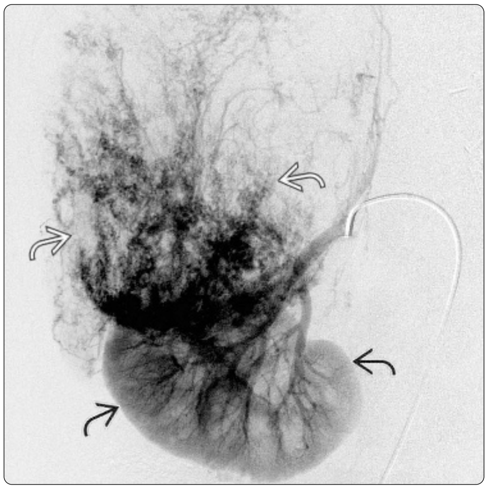
(Left) *A selective left lower pole branch angiogram reveals this vessel* → *to be the dominant supplier to the AML* ⇨*. Minimal normal renal parenchyma was seen on injection of this vessel.* **(Right)** *Through a microcatheter advanced through and slightly beyond the tip of the 5-Fr catheter, embolization was performed using a total of 3.0 mL of a mixture of 70% absolute alcohol with 30% iodized oil, given in 0.5-mL aliquots. The Lipiodol cast is seen* ➡*. Repeat angiogram (not shown) showed no residual perfusion of the AML.*

(Left) *Coronal CECT in a patient with tuberous sclerosis shows a very large exophytic AML → arising from the upper pole of the right kidney ⇨. Enhancing vascularity ↪ is present in the mass.* **(Right)** *Right renal DSA shows normal renal parenchyma ↷ inferiorly and extensive tumor vascularity ↪ in the AML. The vascularity depends on the proportions of the various components of the hamartoma. Hypovascular AMLs have a low bleeding risk and respond poorly to embolization.*

Particle Embolization of AML (Evaluation With CECT)

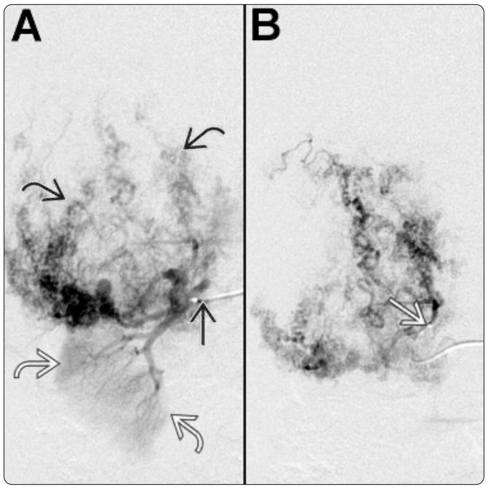


Particle Embolization of AML (Selective Right Renal DSA)

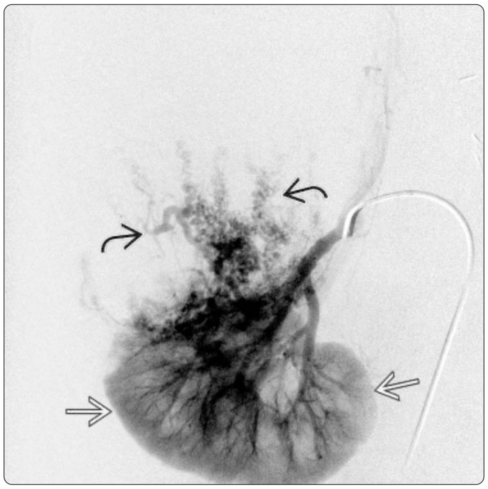


(Left) *(A) A microcatheter → in a segmental renal artery shows both normal renal parenchyma ↪ and tumor vascularity ↷ and must be advanced more selectively for embolization to avoid embolizing normal tissue. (B) Once advanced ➡, only tumor vascularity is seen. Particle embolization was performed from this position with 500 µ particles.* **(Right)** *A postembolization DSA shows preserved renal parenchyma ➡. Since some residual tumor remains ↷, the patient was brought back for additional embolization.*

Particle Embolization of AML (Selective Embolization With Particles)

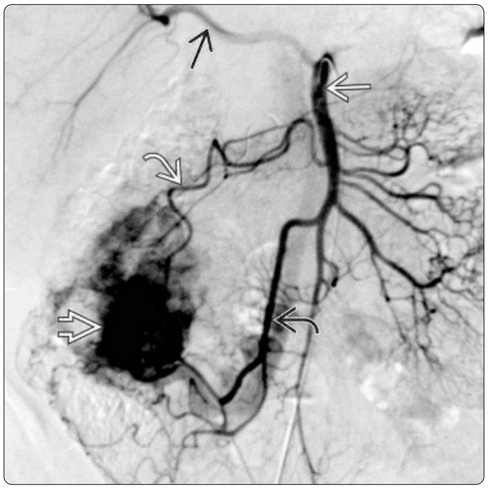


Particle Embolization of AML (Final DSA After Embolization)

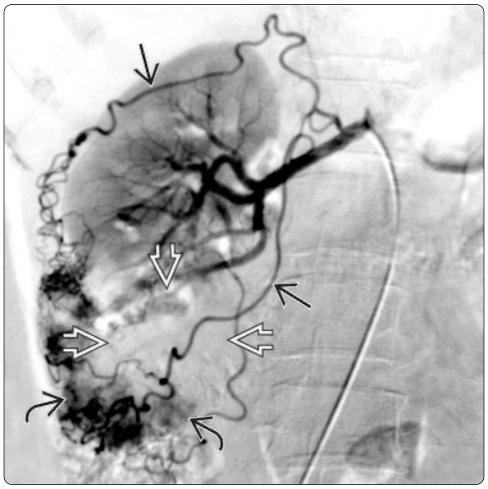


(Left) *SMA angiogram ➡ shows a hypervascular mass ⇨ supplied by the middle colic ↪ and right colic ↷ arteries. This corresponds to the avascular area of the AML noted on the renal DSA. Replaced right hepatic artery →.* **(Right)** *DSA shows an exophytic vascular mass ↷ involving the lower pole of the right kidney with arterial supply from capsular branches → originating from the main renal artery. No vascularity is demonstrated in the central or superior portion ⇨ of the mass suggesting alternative feeding vessels.*

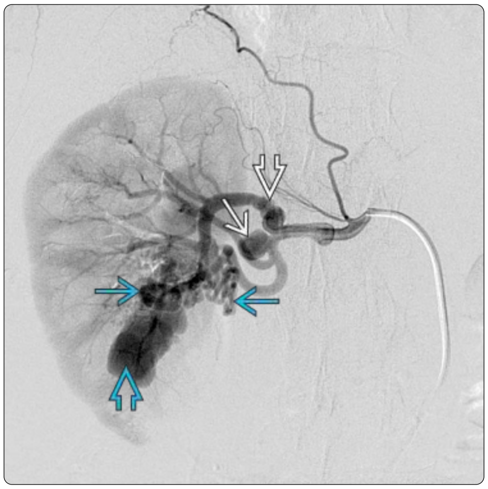
Exophytic AML (Parasitization of Additional Vascularity)



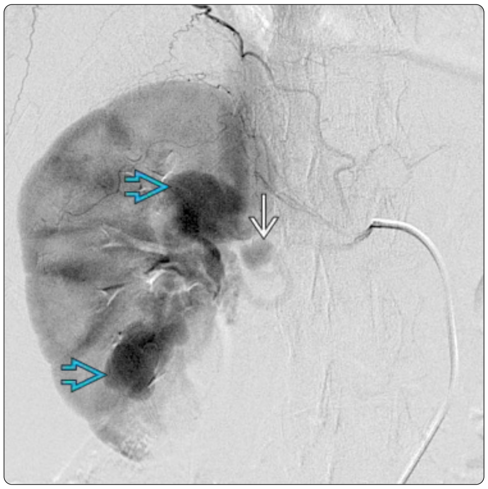
Exophytic AML (Parasitization of Additional Vascularity)



"Glue" Embolization of AVM (Initial Angiogram, Arterial Phase)

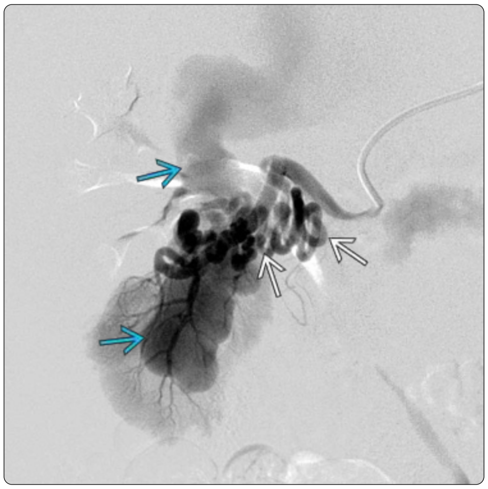


"Glue" Embolization of AVM (Initial Angiogram, Venous Phase)

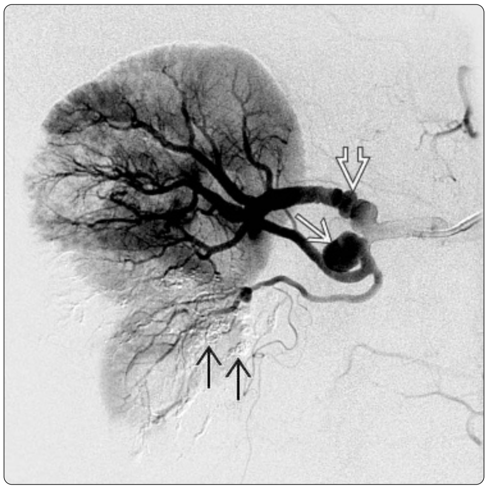


(Left) *A 60-year-old woman with multiple incidentally discovered renal lesions, including a complex arteriovenous malformation with multiple feeding arteries* ⇨ *and enlarged early draining vein* ⇨*, a renal artery aneurysm* ➡*, and changes of fibromuscular dysplasia in the upper pole renal artery* ➡*, is shown.* **(Right)** *Later image from this angiogram shows robust early venous filling* ⇨*. Faint contrast can still be seen in renal arteries. Additionally, pooling of contrast persists in the renal artery aneurysm* ➡*.*

"Glue" Embolization of AVM (Superselective Angiogram)

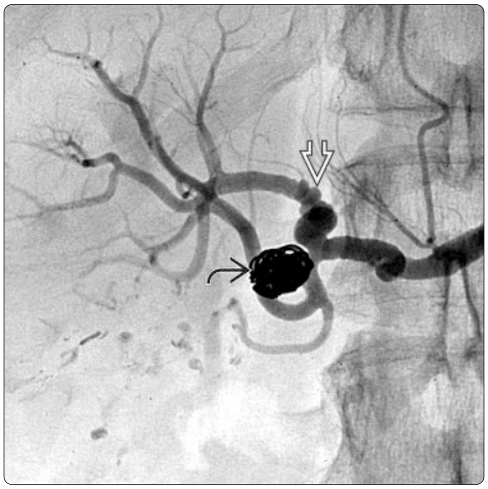


"Glue" Embolization of AVM (Postglue Embolization)

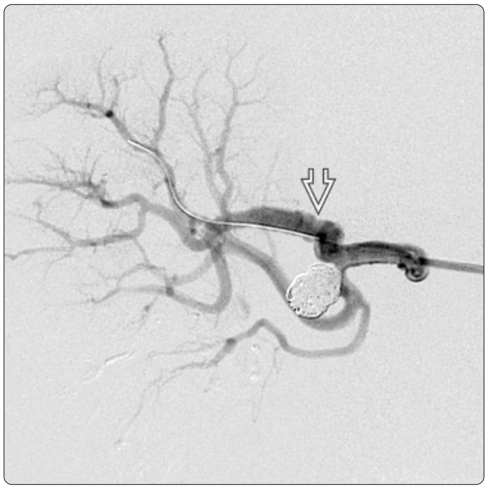


(Left) *The lower pole segmental renal artery was selected and repeat angiogram was done showing multiple feeding vessels* ➡ *arising from this lower pole vessel. Note the markedly enlarged and early draining renal veins* ⇨*.* **(Right)** *Three separate feeding lower pole vessels were embolized using n-butyl cyanoacrylate glue mixed 1:2 with iodized oil* ⇨*. Expected parenchymal loss is seen. No early filling of the renal vein is seen. Again seen is a saccular renal artery aneurysm* ➡ *and FMD of the upper pole renal artery* ➡*.*

"Glue" Embolization of AVM (Postcoil Embolization of Aneurysm)



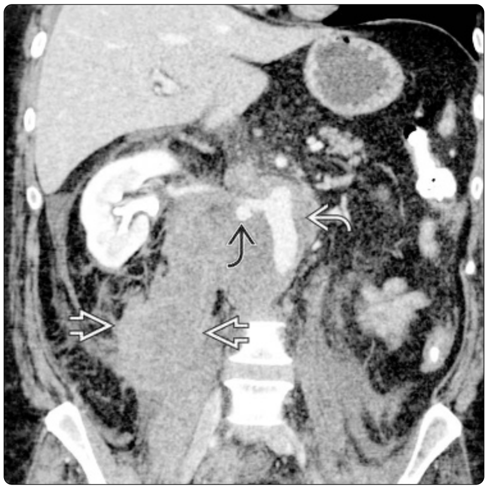
"Glue" Embolization of AVM (Postangioplasty of FMD)



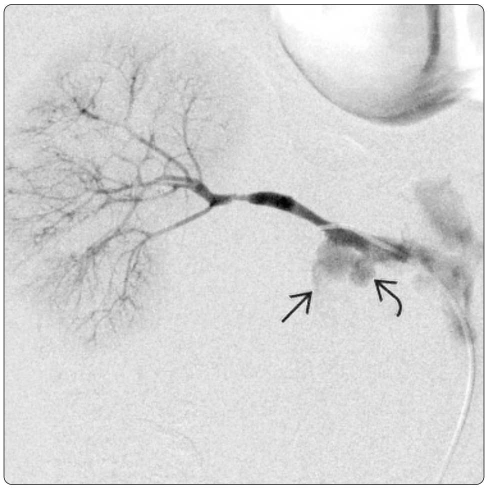
(Left) *This aneurysm was then selected with a microcatheter and the aneurysm was then embolized 1st with 4 detachable 0.018-gauge coils, 1st a 10 mm x 26 cm followed by 8-, 7-, and 6-mm coils* ⇨*. Repeat angiograms showed no perfusion of the aneurysm. Pressure gradient across the area of FMD* ➡ *in the upper pole renal artery was 30 mm Hg.* **(Right)** *Given the gradient, it was decided to treat this lesion. Angioplasty with a 5-mm diameter balloon was performed with marked improvement in appearance* ➡*.*

(Left) *CECT in a patient with a history of spindle cell sarcoma encasing the aorta and right renal artery shows the extensive tumor ➡ eroding the right main renal artery, leading to formation of a PSA ⇨ bleeding into a large retroperitoneal hematoma ➡.* **(Right)** *A right renal artery angiogram shows extravasation of contrast → from the mid to proximal portion of the right renal artery, adjacent to the previously identified PSA ⇨.*

Hemorrhage From Renal Artery Pseudoaneurysm (Coronal CT)

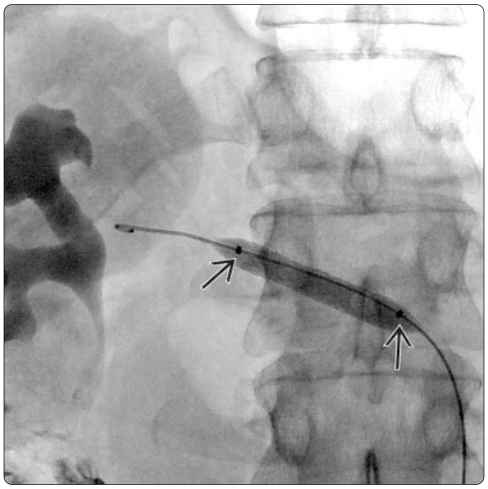


Hemorrhage From Renal Artery Pseudoaneurysm (Renal Artery DSA)

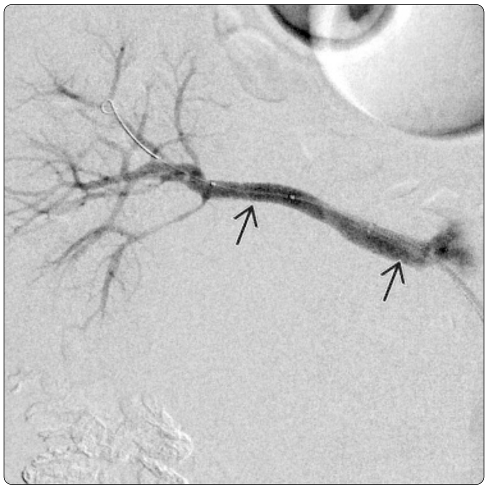


(Left) *Post-stent deployment balloon angioplasty balloon → was then done to lessen the chance of type 1 endoleak.* **(Right)** *Renal artery DSA after covered stent placement shows a normal main renal arterial caliber → and exclusion of the PSA and resolution of the extravasation.*

Hemorrhage From Renal Artery Pseudoaneurysm (Covered Stent)

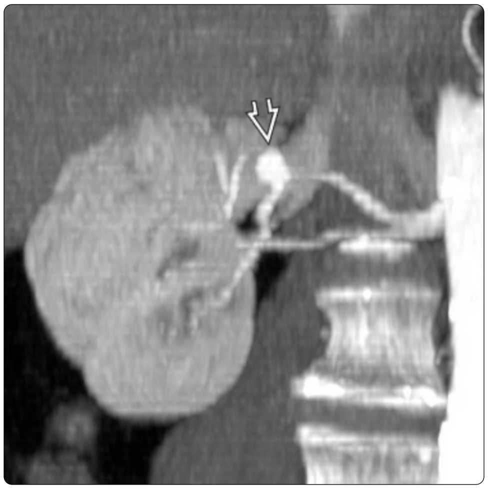


Hemorrhage From Renal Artery Pseudoaneurysm (After Treatment)

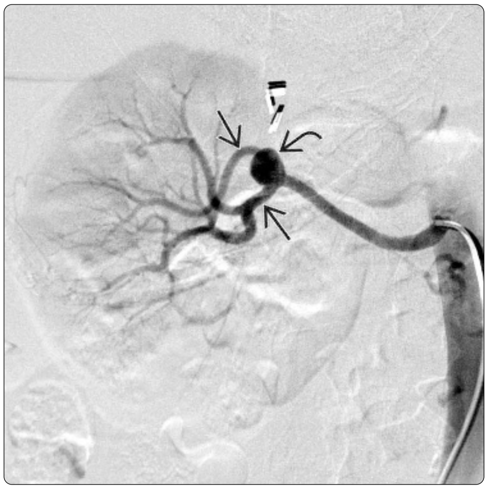


(Left) *Coronal CECT shows that the aneurysm ➡ involves the distal main right renal artery. Coil embolization of this aneurysm (as well as inflow and outflow) would result in an unacceptably large are of renal infarct.* **(Right)** *Renal angiogram shows the 2-cm aneurysm ⇨ arising from the main renal artery. Renal artery aneurysms frequently occur at bifurcation points. In this case, 2 large branch vessels → arise from the aneurysm.*

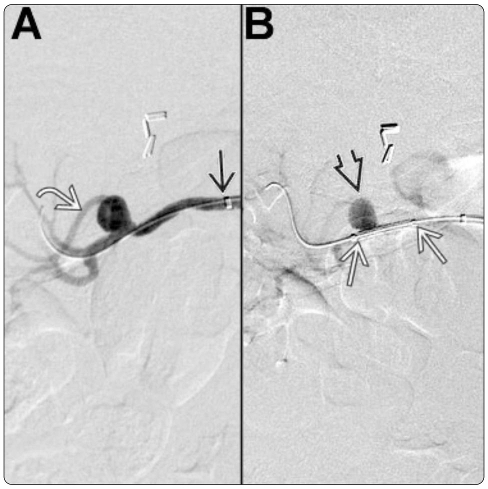
Renal Artery Aneurysm (Initial CECT Evaluation)



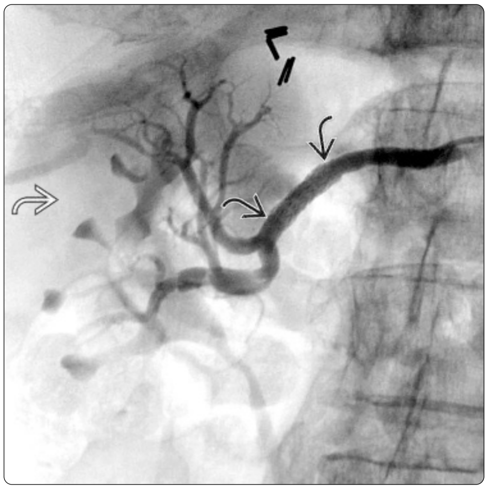
Renal Artery Aneurysm (Right Renal Artery DSA)



Renal Artery Aneurysm (Covered Stent Placement)

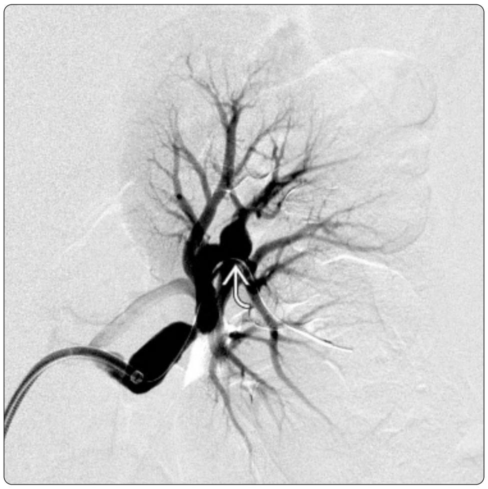


Renal Artery Aneurysm (Angiogram After Stent Graft Placement)

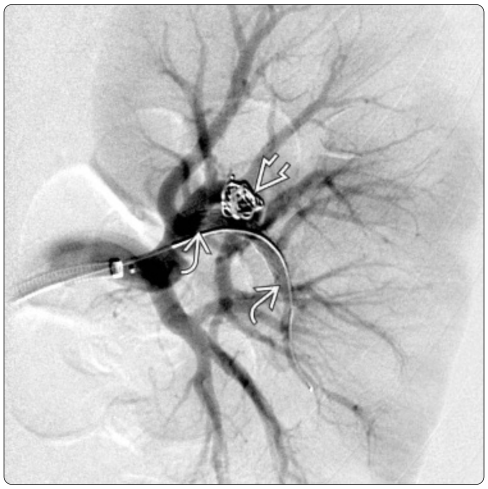


(Left) *(A) A guiding sheath → is advanced into the main right renal artery. The branch vessel ↪ will be sacrificed by stent placement. (B) A balloon-mounted covered stent → has been positioned bridging the aneurysm and will be inflated in this location to exclude the aneurysm ⇨.* **(Right)** *The covered stent ↪ has successfully excluded the renal artery aneurysm. Moderate-sized area of nonperfusion ↪ of the upper to mid pole of the kidney is seen, an expected consequence of branch vessel occlusion by the stent graft.*

Stent-Assisted Coiling of Intrarenal Aneurysm (Diagnostic Renal Arteriogram)

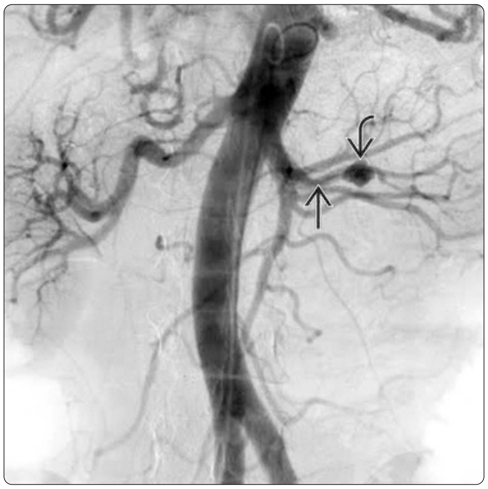


Stent-Assisted Coiling of Intrarenal Aneurysm (Coil Embolization)

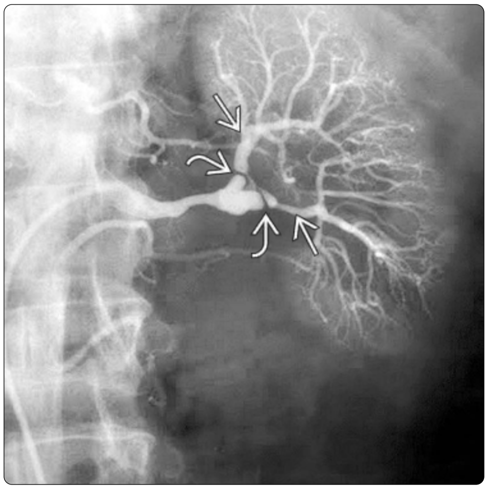


(Left) *With intraparenchymal renal artery aneurysms, coil embolization may be more appropriate than covered stent placement. If the aneurysm has a wide neck ↪, stent-assisted coil embolization may be helpful.* **(Right)** *A noncovered stent ↪ is deployed across the neck of the aneurysm. A microcatheter tip is then introduced into the aneurysm through the stent interstices, and microcoils ⇨ are used to pack and exclude the aneurysm, as shown in this DSA.*

Procedural Complication (Arterial Dissection)



Procedural Complication (Arterial Dissection)



(Left) *Aortogram demonstrates a lobulated aneurysm ↪ located near the renal hilum and arising from the main left renal artery →.* **(Right)** *Anteroposterior selective left renal arteriogram shows that there are dissections ↪ present where the 2nd-order branch renal arteries → arise from the aneurysm. The dissections occurred during attempted guidewire passage beyond the aneurysm.*

Pelvic Arteries: Revascularization

KEY FACTS

TERMINOLOGY

- **Aortoiliac occlusive disease**: Stenotic/occlusive disease involving abdominal aorta &/or iliac arteries
  - Also known as Leriche syndrome
    - Classically described as clinical triad
      - Buttock & thigh claudication
      - Absent/decreased femoral pulses
      - Impotence
  - Most commonly due to atherosclerosis

PROCEDURE

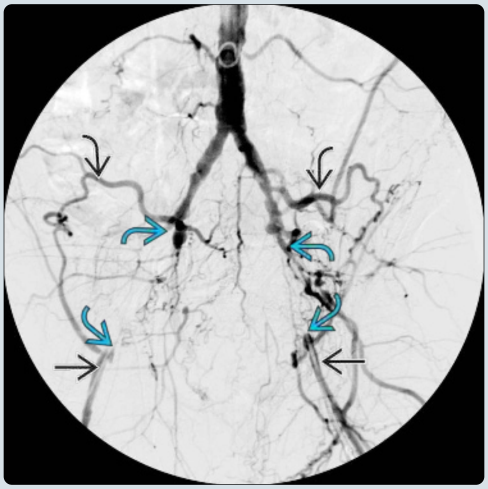
- **General principles of revascularization**
  - May use directional catheter & hydrophilic guidewire combination to cross ipsilateral stenosis/occlusion
  - If access to contralateral iliac artery needed, consider using reverse-curve catheter & crossover sheath
  - Bilateral femoral access may be needed [e.g., "kissing" iliac stents/percutaneous transluminal angioplasty (PTA)]
  - Administer heparin bolus prior to crossing lesion
  - Maintain guidewire across lesion after intervention
  - After intervention, obtain DSA; exclude complications & review results before guidewire removal
- **"Kissing" balloon angioplasty & stents**
  - Revascularization technique for stenotic/occlusive disease of aortic bifurcation/common iliac arteries (CIAs)
  - Involves simultaneously inflating PTA balloons or placing stents in both CIAs
    - Unilateral PTA/stent could displace plaque into contralateral CIA, causing occlusion
  - Requires bilateral common femoral artery access

POST PROCEDURE

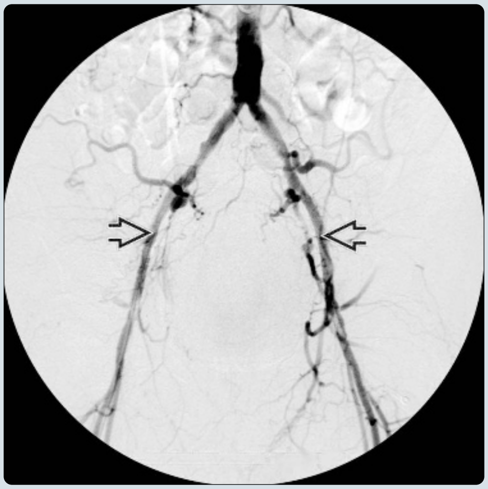
- **Aortoiliac angioplasty/stenting**
  - Technical success rates > 90%
    - Occlusions & stenoses
  - 5-year primary patency rates of 75-85%
    - Assisted primary patency rates of up to 90%
  - Consider long-term antiplatelet therapy

(Left) *Pelvic DSA shows bilateral external iliac artery (EIA) occlusions* ➡, *which are classified as TASC type D lesions &, in the past, would have usually required surgical bypass. Hypertrophied arterial collaterals* ➡ *reconstitute the common femoral arteries* ➡ *bilaterally.* **(Right)** *Pelvic DSA after endovascular revascularization of the occluded EIAs using bilateral angioplasty & placement of noncovered intravascular stents shows restoration of patency* ➡ *to the chronic total occlusions.*

Bilateral Common Iliac Artery Chronic Total Occlusions: Before Intervention

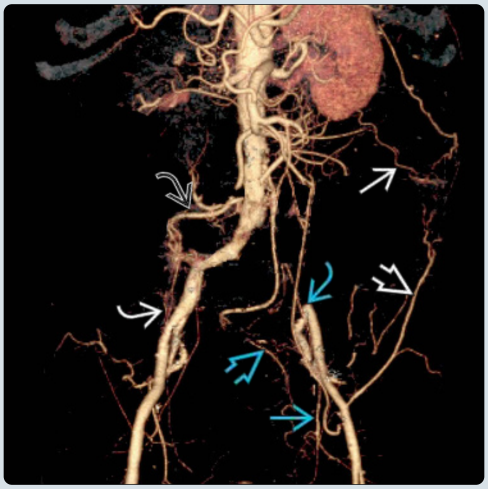


Bilateral Common Iliac Artery Chronic Total Occlusions: After Intervention

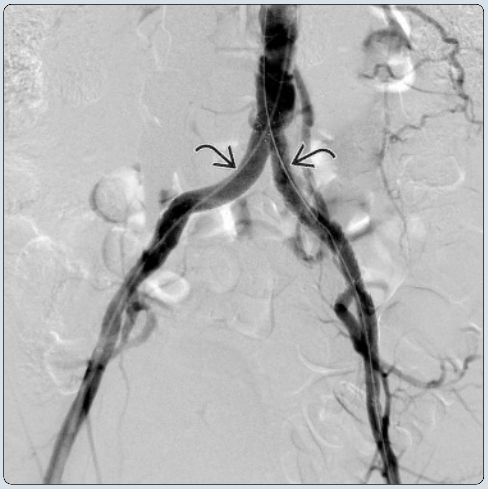


(Left) *This 3D image shows a left common iliac artery (CIA) occlusion extending from the distal aorta to the reconstituted EIA* ➡. *It also shows some of the important collateral pathways that exist. There is a lumbar* ➡ *to iliolumbar* ➡ *connection, a superior rectal* ➡ *to internal iliac artery* ➡ *pathway, & an intercostal* ➡ *to deep circumflex iliac artery* ➡ *route.* **(Right)** *After placing "kissing" covered stents* ➡ *in both CIAs, patency is restored at the prior occlusion, & the collateral pathways no longer fill.*

Aortoiliac Occlusive Disease & Major Arterial Collateral Pathways



Aortic & Pelvic Arteriogram Following Bilateral "Kissing" Stent Placement



TERMINOLOGY

Definitions

- **Aortoiliac occlusive disease**: Stenotic or occlusive disease involving abdominal aorta &/or iliac arteries
  - Also known as Leriche syndrome
    - Classically described as clinical triad
      - Buttock & thigh claudication
      - Absent or decreased femoral pulses
      - Impotence
  - Usually due to peripheral artery disease (PAD)
    - Concurrent atherosclerosis prevalent elsewhere
      - Same atherosclerosis risk factors
  - Varying degrees of severity
    - Range from asymptomatic to rest pain & tissue loss
      - Depends on adequacy of collateral vessels, quality of infrainguinal arterial runoff
  - **Intermittent claudication (IC)**: Reproducible muscular leg pain after walking, relieved with rest
    - Imbalance of supply and demand of blood flow
    - Stable clinical course in 75% of patients
      - Decreasing ankle-brachial index (ABI) best predictor of deterioration
    - Sudden worsening suggests need for intervention
  - **Buttock claudication**: Reproducible cramping pain in buttocks occurring during normal exertion
    - Results from poor perfusion of pelvic muscles; caused by proximal arterial blockage
      - e.g., distal aorta, common iliac arteries (CIAs)/internal iliac arteries
    - Decreasing ABI best predictor of deterioration
  - **Acute limb ischemia (ALI)**: Sudden interruption of arterial blood flow to extremity
    - Usually due to arterial embolus or thrombosis
      - Embolic source may be cardiac or aneurysm
    - Occurs infrequently if only pelvic arteries involved
      - Typically requires concurrent infrainguinal lesion
- **Nonatherosclerotic pelvic arteriopathies**
  - **External iliac artery (EIA) endofibrosis**: Entity specific to endurance athletes, particularly cyclists
    - Caused by repetitive flexion-extension of hip; causes stress lesions in arterial wall
      - Results in intimal subendothelial fibrosis with wall thickening & reduced luminal caliber
    - 90% of cases located in EIA
      - Unilateral in most cases (88%)
    - Presents with exercise-related claudication
      - Limits athlete's performance ability
    - Surgical bypass is mainstay of treatment
  - **Fibromuscular dysplasia (FMD)**: Noninflammatory, nonatherosclerotic disorder affecting long unbranched medium-sized arterial segments
    - 5% reported incidence of iliac artery involvement in patients with renal/carotid artery FMD
      - EIA most commonly involved
      - Usually medial fibroplasia subtype: 80–90%
    - Unusual cause of lower extremity claudication
      - May present with acute limb ischemia from progressive obstruction/microemboli; usually responds well to angioplasty
      - Rarely presents with dissection/rupture; may require surgical bypass
- **Trans-Atlantic Inter-Society Consensus (TASC) II**: Comprehensive PAD management document; classifies anatomic lesions, makes treatment recommendations
  - **TASC II classification of aortoiliac lesions**
    - **Type A lesion**
      - Unilateral/bilateral CIA stenoses
      - Unilateral/bilateral single short (≤ 3 cm) EIA stenoses
    - **Type B lesion**
      - Short (≤ 3 cm) infrarenal aortic stenosis
      - Unilateral CIA occlusion
      - Single/multiple EIA stenoses, totaling 3-10 cm; common femoral artery (CFA) uninvolved
      - Unilateral EIA occlusion not involving origins of internal iliac arteries or CFAs
    - **Type C lesion**
      - Bilateral CIA occlusions
      - Bilateral EIA stenoses 3-10 cm long; stenoses do not extend into CFAs
      - Unilateral EIA stenosis extending into CFA
      - Unilateral EIA occlusion involving internal iliac &/or CFA origins
      - Heavily calcified unilateral EIA occlusion with/without internal iliac/CFA origin involvement
    - **Type D lesion**
      - Infrarenal aortoiliac occlusion
      - Diffuse disease of aorta & both iliac arteries
      - Diffuse multiple stenoses unilaterally involving CIA & EIA plus CFA
      - Unilateral combined occlusions of CIA & EIA
      - Bilateral EIA occlusions
      - Iliac stenoses in AAA not amenable to endovascular aneurysm repair (EVAR); other lesions requiring open aortic/iliac surgery
  - **TASC II categories: Treatment recommendations**
    - **Type A**: Endovascular procedures recommended
      - Should be 1st-line treatment
    - **Type B**: Endovascular procedures recommended
      - Unless concurrent surgery for adjacent lesions
    - **Type C**: Open revascularization recommended
      - Endovascular procedures recommended only if potential for poor healing after open surgery
    - **Type D**: Endovascular procedures not recommended as 1st-line treatment
  - TASC III Consensus guidelines currently being considered
- **American College of Cardiology & American Heart Association Guidelines for PAD Management**
  - Document addressing diagnosis & management of atherosclerotic, aneurysmal, & thromboembolic PAD

Pertinent Vascular Anatomy

- **CIA**: Origin at aortic bifurcation; divides into external & internal iliac arteries
  - Typically 4-6 cm long, ≤ 1 cm in diameter
  - Extraperitoneal inferolateral course along medial psoas muscle margin; bifurcates at pelvic brim
- **EIA**: Extends from CIA bifurcation to inguinal ligament
  - Typically 8-10 cm long, 6-8 mm in diameter
  - Anteroinferior course along psoas muscle medially

- Gives origin to 2 major branches
  - **Inferior epigastric artery**
    - Arises immediately above inguinal ligament; cephalad course deep to rectus abdominis
    - Anastomoses with superior epigastric artery (continuation of internal mammary artery)
    - May give rise to obturator artery, or accessory obturator artery (anatomic variant seen in 30%)
  - **Deep circumflex iliac artery**
    - Courses along iliac crest of pelvis
    - Anastomoses with iliolumbar/superior gluteal artery; important collateral in iliac occlusions

- **Internal iliac (hypogastric) artery**: Originates at CIA bifurcation; divides into 2 trunks
  - **Anterior division**: Various branches supply bladder, uterus, external genitalia, prostate, & rectum; also supply buttock & posterior thigh muscles
  - **Posterior division**: Various branches supply psoas, iliacus, gluteal, & erector spinae muscles

PREPROCEDURE

Indications

- Claudication: Limb or buttock claudication
  - Resultant significant disability/lifestyle limitations
    - No improvement from medical/exercise therapy
  - Lesion amenable to endovascular intervention
    - TASC A, B, & some C lesions
      - Also some type D lesions; depends on operator experience, surgical contraindications
- Acute limb ischemia

Contraindications

- Anaphylaxis to iodinated contrast medium
  - May consider CO_2 or gadolinium as alternatives
- Renal insufficiency
- Uncorrectable coagulopathy
- Some TASC C & most TASC D lesions
  - Surgical bypass recommended treatment
    - Must be suitable surgical candidate
  - Increasing evidence that many TASC D lesions can be successfully treated endovascularly

Preprocedure Imaging

- **Noninvasive arterial evaluation**: Several components
  - **ABI**: Ratio of ankle arterial pressure to upper extremity arterial pressure
    - Verifies vascular etiology of extremity pain
    - Performed with BP cuff and continuous Doppler
      - Use higher ankle pressure found in dorsalis pedis or posterior tibialis
      - Divide ankle pressure by brachial artery pressure
    - ABI values
      - Normal: > 1.0
      - Minimal/no ischemic disease: 0.9-1.0
      - Mild to moderate disease: 0.5-0.9
      - Moderate to severe disease: 0.3-0.5
      - Critical limb ischemia: < 0.3
    - ABI > 1.3 suggests calcified vessels
      - Calcification prevents adequate compression of arteries; examination unreliable/nondiagnostic
    - Exercise ABI
      - Use if resting ABI normal; major PAD symptoms
      - More sensitive than resting ABI
      - Abnormal: > 20% ABI decrease compared to rest
  - **Segmental limb pressures**: BP cuffs placed on leg at 4 levels; arterial pressures obtained
    - Cuffs placed at proximal thigh, distal thigh, below knee, above ankle
    - Allows for approximate localization of disease
      - BP drop ≥ 20 mm Hg, dampened waveform indicates flow-limiting lesion between cuffs
  - **Pulse volume recording (PVR)**: Combines segmental limb pressures with air plethysmography
    - Measures changes in limb volume at various levels, reflects changes in blood flow
    - Each cuff inflated to standard pressure; volume changes detected by pressure transducer
      - Pulse volume recordings displayed as waveforms
    - PVR waveforms reflect PAD severity
      - Normal: Sharp systolic upstroke, dicrotic notch in downstroke
      - Mild/moderate disease: Loss of sharp upstroke, loss of dicrotic notch, prolonged downstroke
  - **Duplex US**
    - Characterizes lesion morphology, severity, & extent
    - Findings of stenosis (51-75% luminal narrowing)
      - Prestenotic segment: Normal
      - Intrastenosis: Peak systolic velocity (PSV) elevated > 2x normal
      - Poststenotic segment: Partial turbulence
    - Findings of stenosis (76-99% luminal narrowing)
      - Prestenosis: Increased pulsatility
      - Intrastenosis: Increased PSV > 4x normal
      - Poststenotic segment: Marked turbulence
    - Body habitus/interposed bowel gas may limit study
      - Evaluation of pelvic arteries typically limited
- **CTA**
  - Excellent delineation of arterial anatomy & pathology
    - Characterization of target lesion(s)
  - Similar accuracy to digital subtraction angiography
- **MRA**
  - Excellent delineation of arterial anatomy & pathology
    - Contrast and noncontrast techniques available
- **DSA**
  - Considered gold standard
  - Limited role now in preprocedure evaluation
  - Provides imaging guidance during intervention

Getting Started

- Things to check
  - Clinical history and physical examination
    - Comprehensive cardiovascular evaluation
      - Detailed pulse examination, Doppler evaluation
    - Review prior endovascular & surgical interventions
      - May influence choice of optimal access
    - Current medications
      - Any anticoagulant/antiplatelet agents
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)

        - ☐ Prefer normal Cr; eGFR > 60
    - – CBC
        - ☐ Platelet count > 50,000/μL
    - – Coagulation profile
        - ☐ INR ≤ 1.5
        - ☐ Normal PT, partial PTT
- Medications
    - ○ Agents for moderate sedation
        - – Fentanyl
        - – Midazolam
    - ○ Heparin
        - – Various intraprocedural administration regimens
            - ☐ Bolus dose of 2,500-5,000 U; followed by infusion of 1,000 U/h
            - ☐ Loading dose of 50-100 U/kg; followed by continuous infusion of 15-25 U/kg/h
            - ☐ Follow anticoagulation with activated clotting time: Target value of 250-300 s
    - ○ Vasodilator
        - – Typical bolus dose of 100 μg nitroglycerin
        - – Prevents/treats catheter-induced vasospasm
    - ○ Clopidogrel
        - – Consider loading dose before revascularization
            - ☐ 300-mg minimum loading dose
        - – Continue maintenance dose post procedure
            - ☐ 75-mg daily dose for 4-6 weeks minimum
    - ○ 1-2% lidocaine local anesthesia
- Equipment list
    - ○ Access sheaths
        - – 5- to 8-Fr vascular access sheath
            - ☐ Size depends on catheters/delivery systems
            - ☐ Permits catheter exchanges as necessary
        - – Crossover access sheath (for contralateral access)
            - ☐ e.g., Ansel, Balkin sheaths
    - ○ Catheters
        - – Diagnostic catheter
            - ☐ Flush (e.g., pigtail, OmniFlush) catheter
        - – Selective catheter
            - ☐ Hydrophilic straight/angled catheter
            - ☐ May use to direct guidewire into target artery
        - – Coaxial 2.6- to 3.0-Fr microcatheter
            - ☐ Various proprietary options
        - – Angioplasty (PTA) balloon catheter
            - ☐ Balloon diameter, length based on target lesion
            - ☐ High-pressure vs. low-pressure balloon
            - ☐ Insufflator for balloon inflation
        - – Drug-coated angioplasty balloon catheter
            - ☐ May be considered if angioplasty chosen as 1st-line/primary therapy rather than stenting
        - – Specialty catheters/devices for crossing chronic total occlusion (CTO)
            - ☐ Crosser CTO recanalization catheter (CR Bard; Murray Hill, NJ)
            - ☐ Quick-Cross support catheter (Spectranetics; Colorado Springs, CO)
            - ☐ Wildcat catheter (Avinger; Redwood City, CA)
    - ○ Guidewires
        - – Initial "starting" 0.035" guidewire
        - – Angled or straight-tipped hydrophilic guidewire
            - ☐ Often beneficial for selective catheterization
        - – Stiff guidewire (e.g., Amplatz, Lunderquist, Rosen)
            - ☐ Stability when advancing/placing devices
        - – 0.014-0.018" microwire
            - ☐ For use with microcatheter
    - ○ Stents
        - – Noncovered self-expanding or balloon mounted
        - – Covered self-expanding or balloon mounted
    - ○ **Reentry catheters & devices**
        - – Outback catheter (Cordis; Miami Lakes, FL)
            - ☐ Radiopaque markers allow fluoroscopic device orientation for directing curved reentry needle
        - – Pioneer catheter (Medtronic; Minneapolis, MN)
            - ☐ Equipped with intravascular US probe to identify true lumen for curved reentry needle

PROCEDURE

Patient Position/Location

- Best procedure approach
    - ○ Typically CFA access
        - – Access may be ipsilateral/contralateral to target
            - ☐ Determined by revascularization target location
    - ○ Brachial artery access occasionally required
        - – Avoid introducing large-caliber devices if possible
            - ☐ Small artery, susceptible to injury

Procedure Steps

- **General**
    - ○ **Initial arterial access**
        - – Sterilely prepare & drape intended access site
        - – Administer 1-2% lidocaine local anesthesia
        - – Challenging if ipsilateral severe stenosis/occlusion
            - ☐ Nonpalpable/faintly palpable femoral pulse
        - – Consider US guidance during arterial access
            - ☐ May be problematic if large body habitus
        - – Alternatively place contralateral catheter in aorta
            - ☐ Obtain DSA to opacify contralateral CFA; use DSA for anatomic guidance during access
    - ○ **DSA evaluation of anatomy**
        - – After obtaining arterial access, insert sheath
            - ☐ Introduce flush/selective catheter via sheath
        - – Position catheter for initial DSA imaging
            - ☐ e.g., pigtail catheter in distal aorta for pelvic DSA
        - – Alternatively, may use access sheath for retrograde injection prior to introducing catheter
            - ☐ May be useful in delineating CIA or EIA stenosis/occlusion if accessing ipsilateral femoral artery
        - – Inject contrast; obtain DSA images
            - ☐ Review DSA; determine appropriate intervention
        - – Proceed to more selective catheterization if needed for better anatomic delineation with DSA
    - ○ **General principles of pelvic revascularization**
        - – May use directional catheter/hydrophilic guidewire combination to cross ipsilateral stenosis/occlusion
        - – If access to contralateral CIA or EIA needed, consider using reverse-curve catheter & crossover sheath
        - – Bilateral femoral access may be needed (e.g., for "kissing" iliac artery angioplasty & stents)
        - – Confirm catheter position with DSA prior to any intervention; proceed only if satisfactory

        - Administer heparin bolus prior to crossing lesion
        - Monitor fluoroscopically during treatment
    - Avoid extending EIA stents distally below inguinal ligament if possible
    - Can cross origin of internal iliac artery with noncovered stent if necessary
        - Patency maintained in > 90% of cases
    - Maintain guidewire across lesion after intervention
        - Allows additional interventions if necessary, without recrossing treatment zone
    - Following intervention, obtain DSA
        - Document results/exclude complications
    - If satisfactory result, carefully withdraw guidewire
        - Remove guiding catheter/guiding sheath
  - **Completion of procedure & hemostasis**
    - If manual compression planned for hemostasis
        - Remove access sheath; compress puncture site
    - If closure device planned for hemostasis
        - Deploy per manufacturer's instructions
- **Atherosclerotic stenosis revascularization**
  - Delineate proximal & distal extent of lesion with DSA
  - Position catheter proximal to target stenosis
    - Administer heparin bolus prior to crossing lesion
        - Typical heparin bolus dose: 2,500-5,000 U
  - Use catheter & hydrophilic guidewire to cross stenosis
    - Gently advance guidewire across stenosis
        - Imperative to avoid vessel dissection
  - If resistance to guidewire passage encountered
    - **Do not** continue to advance guidewire; continued advancement may cause dissection
    - Consider different catheter or guidewire shape
  - Keep catheter parallel to vessel centerline
    - Must direct guidewire through central channel of stenosis, even if extremely eccentric
  - Advance catheter over guidewire, across stenosis
    - Once catheter beyond lesion, place stiff guidewire (e.g., Amplatz, McNamara, Lunderquist, Rosen)
  - Exchange for PTA catheter or stent delivery system
    - For primary stenting, consider predilatation with angioplasty; creates passage for stent delivery
  - If performing angioplasty, base balloon size on adjacent normal vessel diameter
    - Significant oversizing of balloon risks vessel rupture, accelerated intimal hyperplasia, & restenosis
  - Maintain guidewire position across lesion when performing angioplasty or placing stent
  - Center PTA balloon or stent to lesion
    - Overlapping angioplasties may be required
    - Stent should extend across entire lesion
  - Perform angioplasty &/or place stent
  - Inject contrast through guiding catheter/sheath while guidewire remains across treatment zone
    - Exclude complications; document results
  - If satisfactory result confirmed, remove guidewire, catheters, & sheaths; obtain hemostasis
- **CTO revascularization**
  - Various methods for revascularizing CTOs
    - **Intraluminal recanalization**
        - Guidewire & catheter combination used to traverse chronically thrombosed & plaque-filled arterial lumen
        - Must initially penetrate proximal edge of CTO
        - Negotiate entire length of CTO with guidewire & catheter while remaining intraluminal
        - Enter reconstituted patent lumen beyond CTO
    - **Subintimal recanalization**
        - Intentional extraluminal guidewire & catheter passage in subintimal space during CTO revascularization
        - Subintimal space is path of least resistance in CTO; allows fairly easy passage
        - Requires guidewire & catheter reentry into reconstituted distal arterial segment
    - **Subintimal recanalization with sharp reentry**
        - Specialized reentry catheter used to regain distal intraluminal access after subintimal recanalization
        - Perform standard subintimal recanalization
        - If catheter fails to reenter artery distally, use dedicated reentry catheter needle to pierce through intima
        - Introduce microwire via needle into true lumen; allows catheter placement across CTO
    - **Subintimal arterial flossing with antegrade-retrograde intervention (SAFARI) technique**
        - Retrograde puncture of reconstituted distal artery after unsuccessful antegrade recanalization attempt
        - Follow with retrograde subintimal recanalization
        - Snare retrograde guidewire via antegrade catheter
        - Creates "flossing" guidewire across lesion
- **"Kissing" balloon angioplasty & stents**
  - Revascularization technique for stenotic/occlusive disease of aortic bifurcation/CIAs
    - Obtain bilateral CFA artery access
        - Place arterial access sheaths bilaterally
    - Use guidewire & catheter combination to cross CIA stenosis/occlusion
    - Choose either bilateral angioplasty or stenting
        - Current practice favors stenting over angioplasty
        - May consider angioplasty with selective stenting
        - If angioplasty chosen as 1st-line therapy, consider using drug-coated balloon
    - Stent options include balloon-mounted vs. self-expanding, noncovered vs. covered stent
        - Self-expanding stent may require subsequent angioplasty to distend stent
        - Some investigators suggest better results with covered stents; care must be taken not to cover side branches
    - Position PTA balloon/stent in each CIA, spanning lesion
    - Simultaneously inflate PTA balloons or place stents in both CIAs
        - Caution: Unilateral PTA/stent could displace plaque into contralateral CIA
    - May extend stents slightly into distal aorta
        - Lesion(s) often involve distal aorta
    - Maintain guidewire access across lesions

  - Obtain DSA to exclude complications & evaluate results
  - If satisfactory result confirmed, remove guidewire, catheters, & sheaths; obtain hemostasis
- **Covered endovascular reconstruction of aortic bifurcation (CERAB) technique**
  - Recently introduced revascularization technique for treating stenotic/occlusive disease of aortic bifurcation/CIAs
    - Large-caliber covered stent placed 15 to 20 mm above native aortic bifurcation
      - Stent distended proximally to aortic wall diameter using large caliber balloon
      - Stent allowed to taper in diameter distally, creating cone-shaped stent
    - 2 iliac covered stents extended into distal conic aortic segment and simultaneously inflated
      - Makes tight connection with aortic stent, as if they were molded together
      - Simulating new aortic bifurcation.
    - Reported higher patency rate than "kissing" stent/balloon technique

Alternative Procedures/Therapies

- Surgical
  - **Surgical revascularization**
    - Aortobifemoral bypass surgery for bilateral iliac artery occlusive disease
    - Femoro-femoral bypass for unilateral disease
      - Must have adequate ipsilateral arterial inflow
- Other
  - Medical management & exercise regimen (claudicants)

POST PROCEDURE

Things to Do

- Consider lifelong antiplatelet therapy
  - Aspirin (81 mg or 325 mg daily)
  - Clopidogrel (75 mg daily)
    - May prescribe for 6-12 weeks, then discontinue
- Close clinical follow-up
  - May include periodic surveillance with ABIs
- Risk factor modification
  - Hyperlipidemia
    - Should be optimally controlled
    - Place patient on statin if appropriate
  - Hypertension
    - Should be optimally controlled
  - Tobacco use
    - Discourage smoking patient from any continued tobacco use
    - Refer to smoking cessation program
  - Diabetes
    - Ensure optimal glycemic control

OUTCOMES

Complications

- Most feared complication(s)
  - Arterial dissection
    - May require secondary stent placement
  - Arterial rupture (rare)
    - Treatment with covered stent placement or emergency surgical repair
  - Distal embolization of plaque or thrombus
    - May cause acute intraprocedural arterial occlusion
- Immediate/periprocedural complication(s)
  - Arterial dissection/thrombosis
  - Access site complications
    - Groin hematoma (3%), pseudoaneurysm (1%), iatrogenic arteriovenous fistula (0.2%)
  - Allergic/anaphylactic reaction to contrast
  - Contrast-induced nephropathy
- Delayed complication(s)
  - Stent occlusion or thrombosis
    - Results mainly from neointimal hyperplasia
      - In-stent stenoses typically respond well to angioplasty
      - Many advocate using drug-coated balloons to treat in-stent stenoses for more durable outcomes

Expected Outcomes

- **Aortoiliac angioplasty/stenting**
  - Technical success rates > 90% when treating occlusions & stenoses
  - 5-year primary patency rates of 75-85%
    - Assisted primary patency rates of up to 90%
  - Some reports of better long-term patency with stenoses vs. occlusion; other reports of equal results

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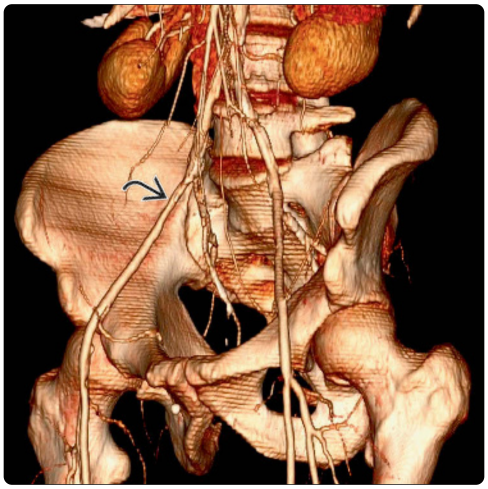
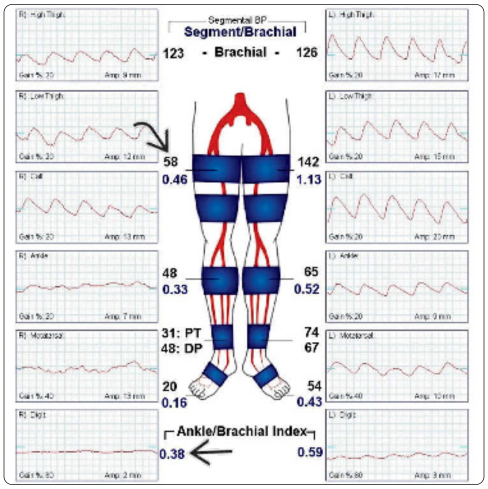
(Left) *Preprocedure imaging is integral to evaluating & managing vascular disease. Initial US screening may be followed by more definitive imaging if indicated. This patient with right leg claudication had a positive noninvasive arterial study. However, a CTA showed only a mild EIA stenosis* ↷*, & no intervention was performed.* **(Right)** *The symptoms worsened 2 years later, & a new noninvasive study was obtained. This shows reduced right segmental pressures* ↷ *& a low ankle-brachial index (ABI)* ⇨*.*

Preprocedure Imaging: Stenosis (Reformation of 3D CTA)

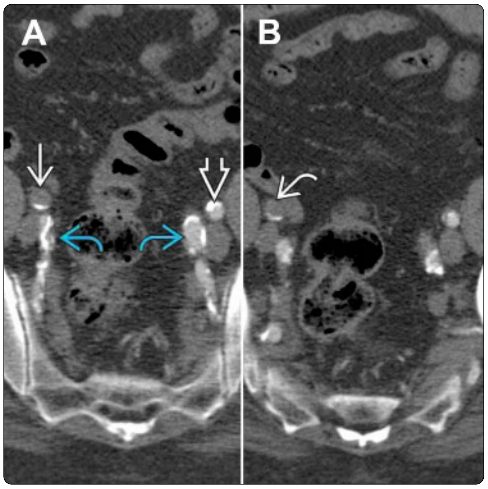


Preprocedure Imaging: Noninvasive Arterial Evaluation

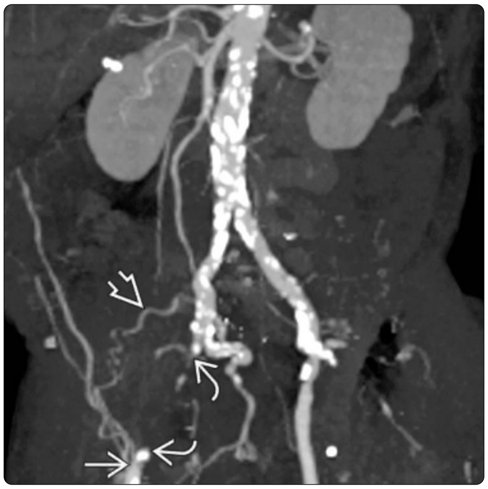


(Left) *Given the noninvasive findings, a repeat CECT was obtained. This shows (A) right EIA occlusion* ➡ *distal to the CIA bifurcation. The left EIA* ➡ *is diseased but patent, as are both internal iliac arteries* ↷*. (B) Distally, the right EIA occlusion* ➡ *is again evident.* **(Right)** *A coronal oblique CT reconstruction shows the extent of the EIA occlusion* ⇨ *& arterial collaterals* ➡ *that reconstitute the proximal right common femoral artery* ➡*.*

Preprocedure Imaging: Iliac Occlusion (Contrast-Enhanced CT)

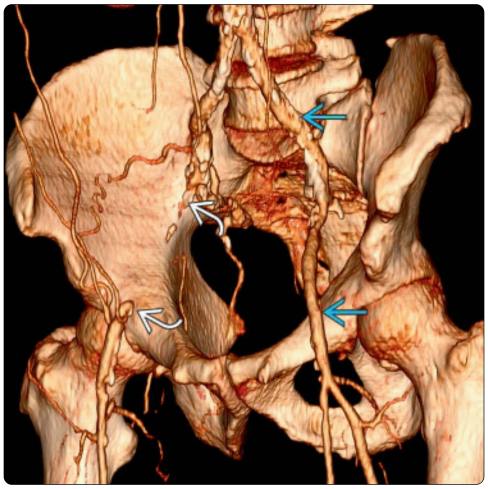


Preprocedure Imaging: Iliac Occlusion (Reconstruction of CTA)

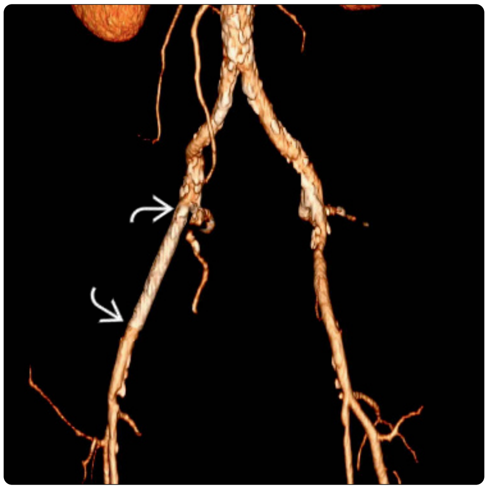


(Left) *CTA is useful in planning interventions. Here, the patent left iliofemoral arteries* ➡ *(same patient) are a potential access route for treatment. The anatomy of the right chronic total occlusion* ➡ *& of the reconstituted distal arterial segment is well seen.* **(Right)** *The patient underwent right EIA stenting with resolution of symptoms. CTA afterward shows a satisfactory stent* ➡ *position. The source CECT images must be carefully evaluated on all follow-up studies to exclude in-stent intimal hyperplasia or occlusion.*

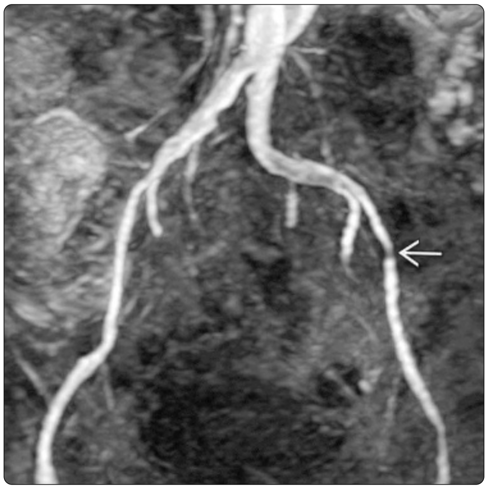
Preprocedure Imaging: Access Planning (Reformation of 3D CTA)



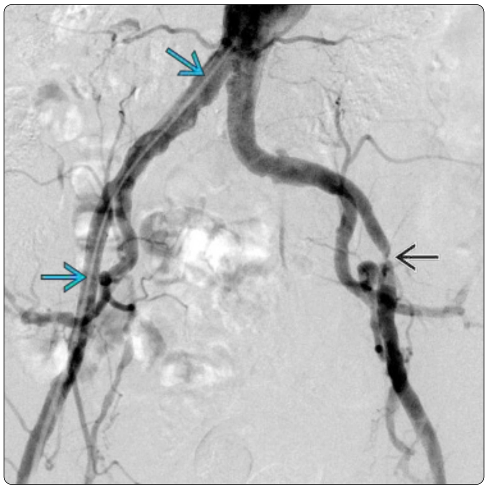
Postprocedure Imaging: Stent Position (Reformation of 3D CTA)



External Iliac Artery Stenosis: Initial Pelvic MRA Evaluation

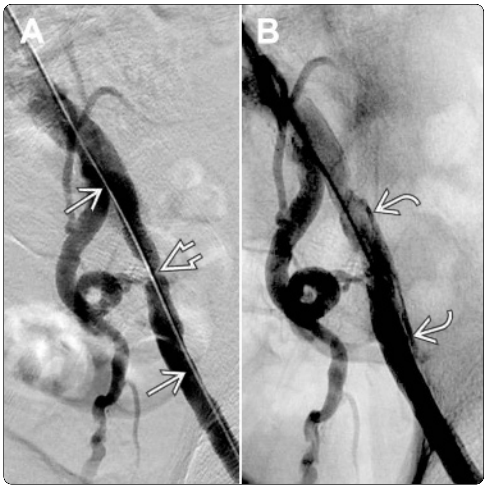


External Iliac Artery Stenosis: Initial Pelvic DSA Evaluation

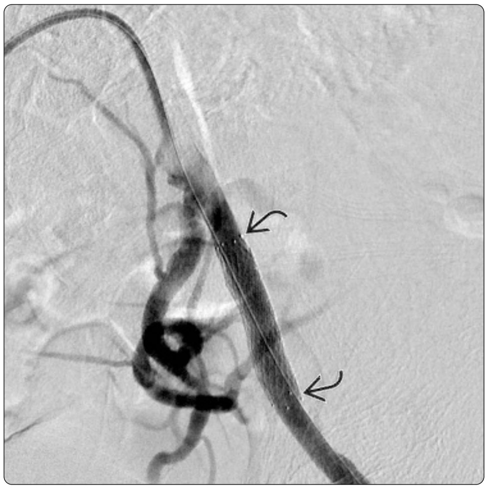


(Left) *Pelvic MRA in a patient with left leg claudication shows a focal left EIA stenosis* ➔ *with no other obvious lesions. The patient subsequently underwent DSA; the intent was to angioplasty the lesion.* **(Right)** *Pelvic DSA via a catheter* ⇨ *introduced from the right common femoral artery confirms the severe focal stenosis* ⇨ *in the left EIA. After obtaining DSA from the right-sided access, the plan was to place a crossover sheath into the contralateral CIA for treatment.*

External Iliac Artery Stenosis: Revascularization With Angioplasty

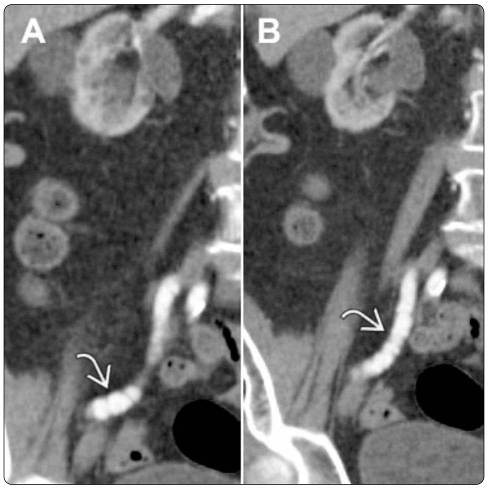


External Iliac Artery Stenosis: Balloon-Mounted Stent Placement

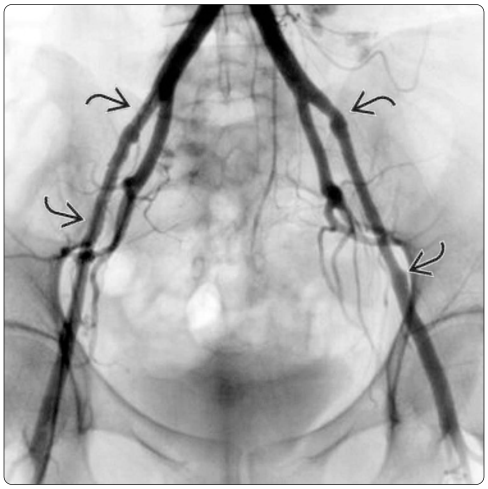


(Left) *(A) After placing a crossover sheath into the left CIA, a coaxial catheter was advanced more distally, & a guidewire* ➔ *was advanced across the stenosis* ➔*. (B) After angioplasty was performed, a repeat angiogram was obtained. This shows intimal clefts* ➔ *that are typically seen after PTA. Delayed images also showed an intraluminal intimal flap.* **(Right)** *Given the intimal flap, it was elected to place an intravascular stent. A balloon-mounted stent* ⇨ *was deployed, spanning the lesion with an excellent result.*

External Iliac Artery FMD: Initial Evaluation With CTA



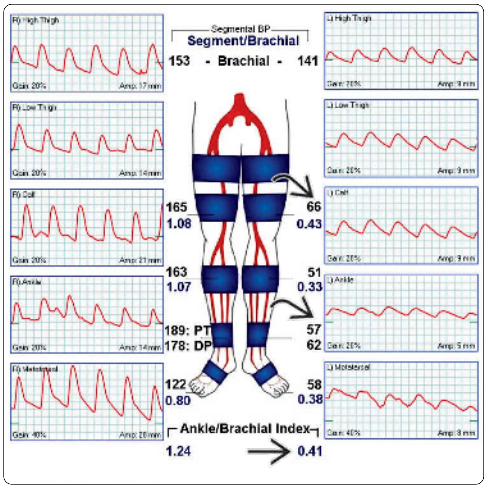
External Iliac Artery FMD: Angiographic Evaluation



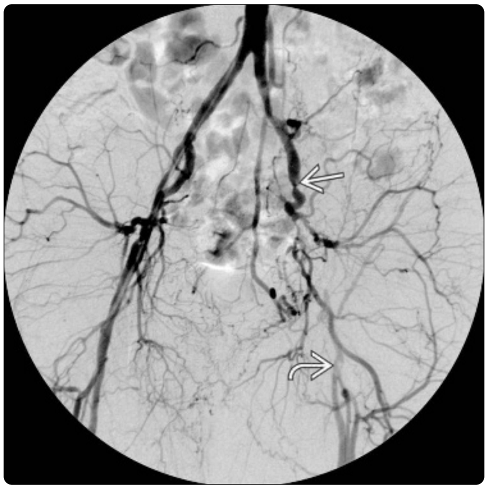
(Left) *Fibromuscular dysplasia (FMD) is a known, albeit uncommon, cause of lower extremity claudication, reportedly involving the EIAs in 5% of patients with renal or carotid FMD. Coronal CTA of the right EIA obtained (A) in the mid pelvis & (B) slightly more posteriorly shows the string-of-beads appearance* ➔ *typical of this entity.* **(Right)** *Pelvic arteriogram shows the typical angiographic appearance of FMD involving the EIAs* ⇨ *bilaterally. This usually responds well to angioplasty.*

(Left) *Noninvasive arterial evaluation of both lower extremities in a patient with claudication shows diffusely decreased segmental limb pressures ⇨ in the left vs. the right leg, beginning at high thigh level. The ABI ⇨ is abnormally low. The findings are consistent with left pelvic arterial inflow disease.* **(Right)** *Based on the symptoms & noninvasive findings, the patient underwent pelvic DSA. This shows left EIA occlusion ➡ with common femoral artery reconstitution ➥ via extensive collaterals.*

External Iliac Artery Occlusion: Noninvasive Arterial Evaluation

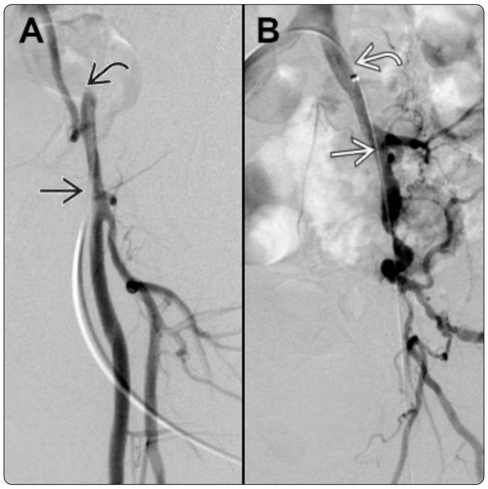


External Iliac Artery Occlusion: Initial Pelvic DSA Evaluation

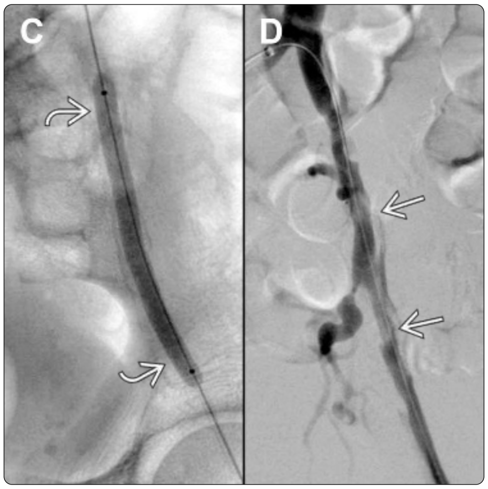


(Left) *Recanalization of the occluded left EIA was done using a combined antegrade-retrograde (SAFARI) approach. (A) A catheter ⇨ was placed in the reconstituted common femoral artery & advanced to the occlusion ↪. (B) A guidewire ➡ was advanced across the occlusion & was snared via a crossover sheath ➥ in the CIA.* **(Right)** *(C) An angioplasty balloon ➥ was used to perform PTA of the occlusion. (D) DSA after PTA shows restored patency but marked luminal irregularity ➡.*

External Iliac Artery Occlusion: Antegrade-Retrograde Recanalization

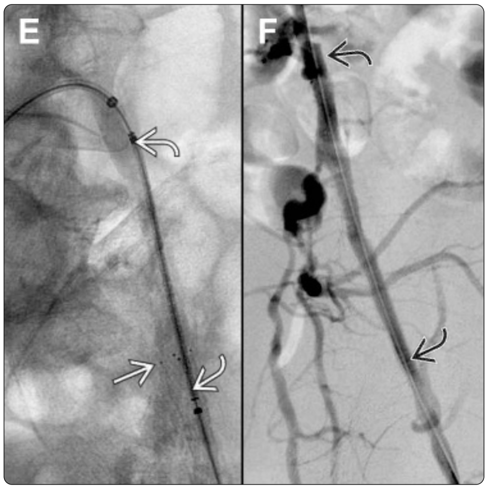


External Iliac Artery Occlusion: Revascularization With Angioplasty

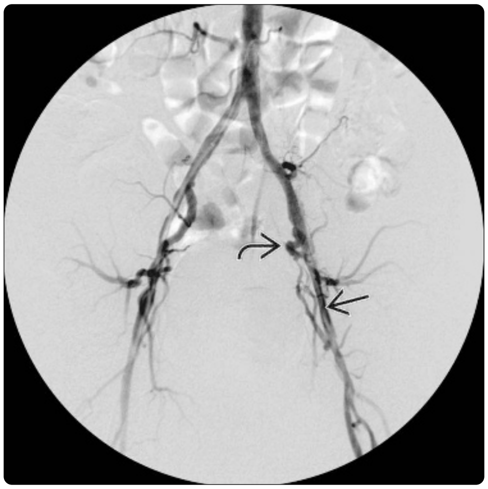


(Left) *Self-expanding stents were placed in the CIAs & EIAs. (E) Image shows a deployed stent distally ➡ with an undeployed stent ➥ that will be placed proximally. (F) DSA after placing overlapping stents shows a satisfactory luminal caliber along the treatment zone ↪.* **(Right)** *Pelvic DSA after revascularizing the left EIA chronic total occlusion via angioplasty & stenting shows patency of the target vessel ⇨ with preserved perfusion of the left internal iliac artery ↪. The previously seen pelvic collaterals no longer fill.*

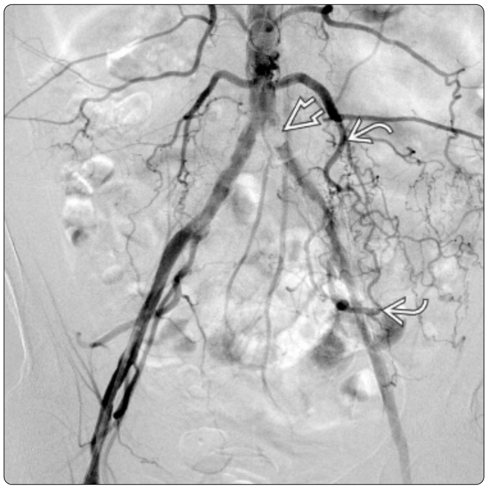
External Iliac Artery Occlusion: Self-Expanding Stent Placement



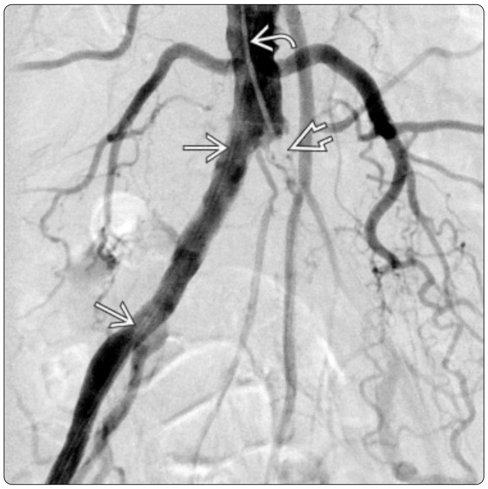
External Iliac Artery Occlusion: Pelvic DSA After Revascularization



"Kissing" Common Iliac Artery Stents: Initial Pelvic DSA Evaluation

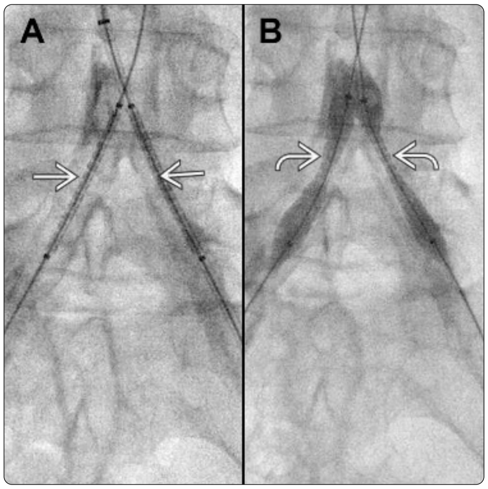


"Kissing" Common Iliac Artery Stents: Guidewire Placement Across Lesion

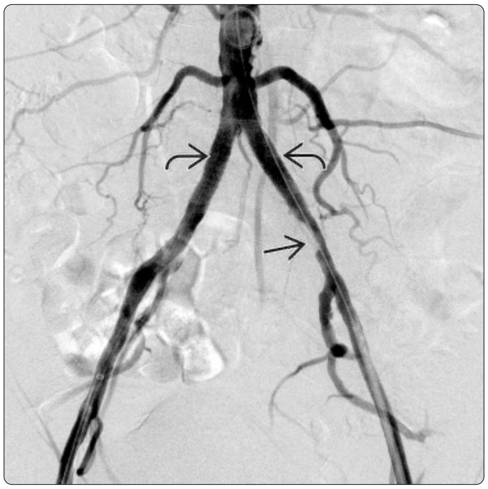


(Left) *Pelvic DSA in a patient with left buttock & lower limb claudication shows a focal subtotal occlusion ⇨ of the proximal left CIA. Extensive iliolumbar arterial collaterals ↪ provide supplemental perfusion distal to the lesion.* **(Right)** *The initial DSA was obtained via a catheter → placed from a right femoral arterial access. Left femoral access has also been obtained, & a catheter & guidewire ↪ have been successfully advanced across the left CIA lesion ⇨, followed by systemic heparinization.*

"Kissing" Common Iliac Artery Stents: Bilateral Balloon-Mounted Stents

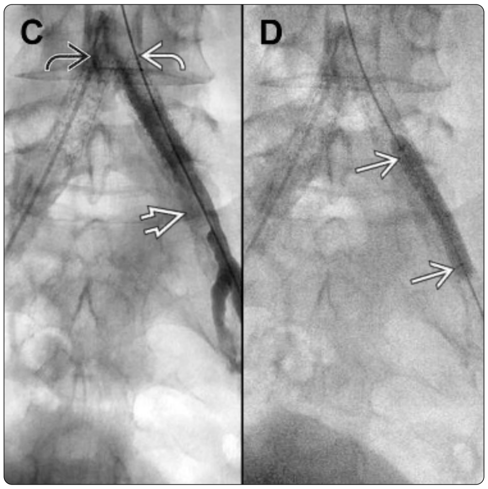


"Kissing" Common Iliac Artery Stent: Pelvic DSA After "Kissing" Stents

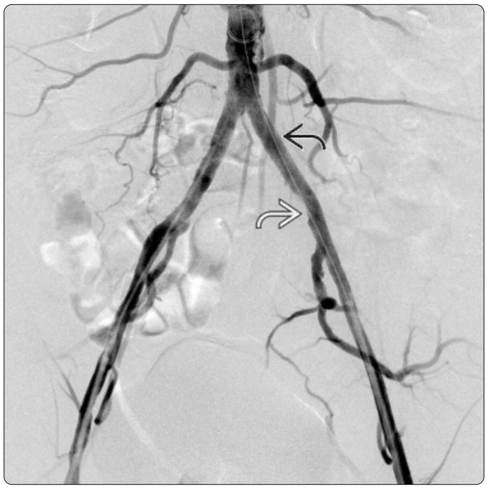


(Left) *Aortic bifurcation lesions often are treated with a "kissing" technique, in which either PTA balloons or stents are used simultaneously in both CIAs. Unilateral treatment could displace plaque into the opposite CIA, causing occlusion. (A) Balloon-mounted stents → are positioned in both CIAs & (B) simultaneously deployed ↪.* **(Right)** *DSA after "kissing" stents shows good stent ↪ positions & a normal left CIA caliber with a small residual distal stenosis →.*

"Kissing" Common Iliac Artery Stents: Additional Stent Placement



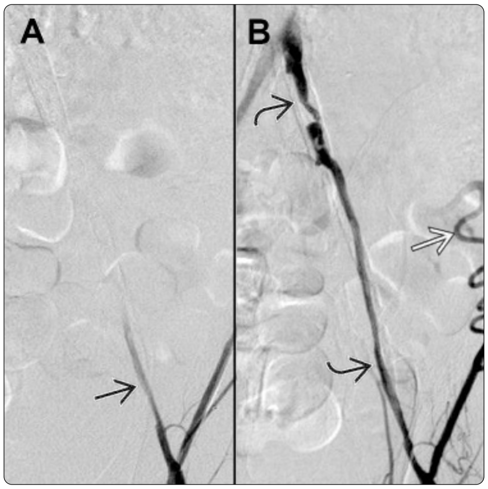
"Kissing" Common Iliac Artery Stents: Final Pelvic DSA After Stenting



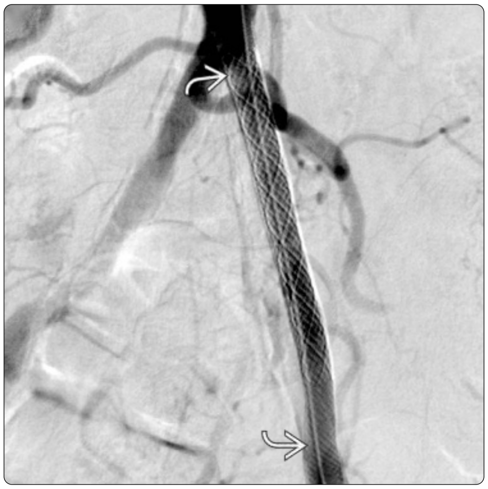
(Left) *(C) Guidewires ↪ or catheters ↪ were left across lesions until DSA confirmed a satisfactory result. Due to the residual distal left CIA stenosis from eccentric plaque ⇨, (D) an additional balloon-mounted stent → was placed overlapping the proximal one.* **(Right)** *Pelvic DSA after "kissing" bilateral CIA stents & left-sided distal stent extension shows patency ↪ & normal caliber ↪ at all treated levels. As before, access was maintained across treatment zones until confirmation of results.*

(Left) *A known sequela of stenting is intimal hyperplasia, causing in-stent stenosis or occlusion. (A) DSA via retrograde contrast injection through a left femoral sheath shows filling of a diminutive lumen ⇨ within a previously placed left external iliac stent. (B) More vigorous injection shows diffuse in-stent stenosis ↪ & filling of a large collateral ➡.* **(Right)** *After angioplasty of the stenosis, a covered stent ↪ was placed inside of the stenotic stent & expanded with repeat angioplasty. This eliminated the stenosis completely.*

In-Stent Stenosis Treatment: Initial DSA Evaluation

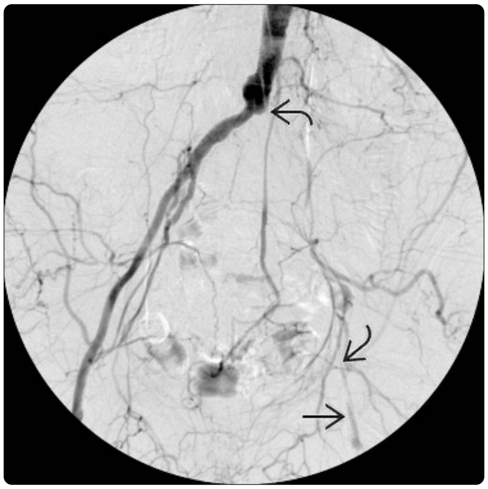


In-Stent Stenosis Treatment: Angioplasty & Stent Placement

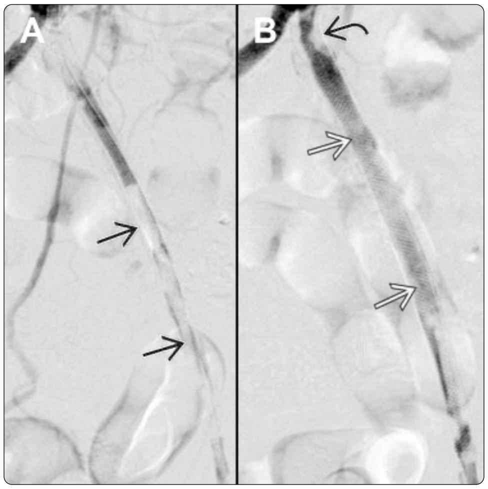


(Left) *Intimal hyperplasia may ultimately cause stent thrombosis & occlusion, as seen in this pelvic DSA from another patient. The left CIA & EIA stents are occluded ↪ with collateral reconstitution of a diminutive left common femoral artery ⇨.* **(Right)** *(A) DSA after crossing the occluded stents shows intraluminal filling defects ⇨ due to thrombosis. (B) After thrombolysis with tPA, partial patency ➡ has been restored to the stents, & a proximal in-stent stenosis ↪ has been demonstrated.*

Thrombosed Stent Treatment: Initial Pelvic DSA Evaluation

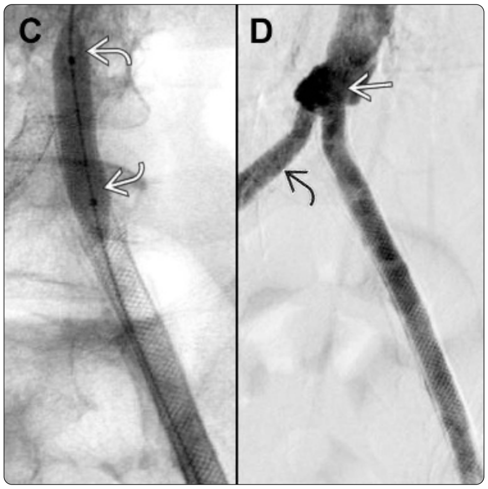


Thrombosed Stent Treatment: Catheter-Directed Thrombolysis

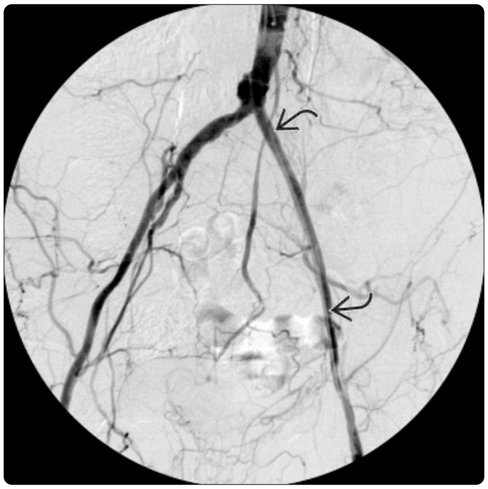


(Left) *(C) PTA ↪ of the in-stent stenosis was performed & (D) was followed by placement of an additional stent that was extended slightly more proximally ➡. A "kissing" stent ⇨ is already in place in the contralateral CIA.* **(Right)** *DSA after thrombolysis, PTA, & additional stenting shows patency ↪ of the previously occluded segment. Secondary interventions can be successful in restoring patency. Five-year primary patency rates of 75-85% are reported after pelvic revascularization with assisted patency rates of up to 90%.*

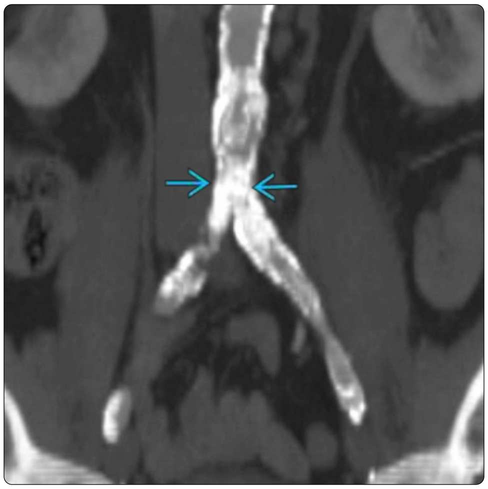
Thrombosed Stent Treatment: Angioplasty & Stent Placement



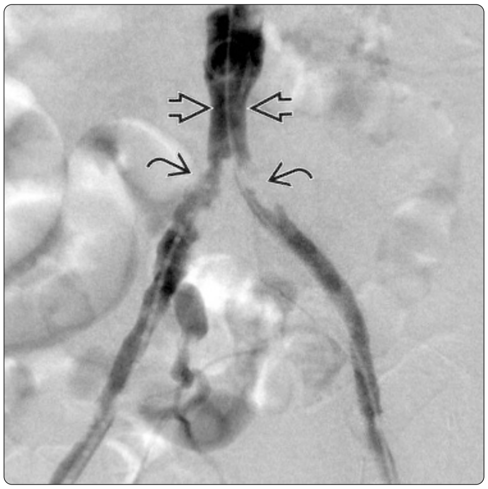
Thrombosed Stent Treatment: Pelvic DSA After Intervention



CERAB Technique

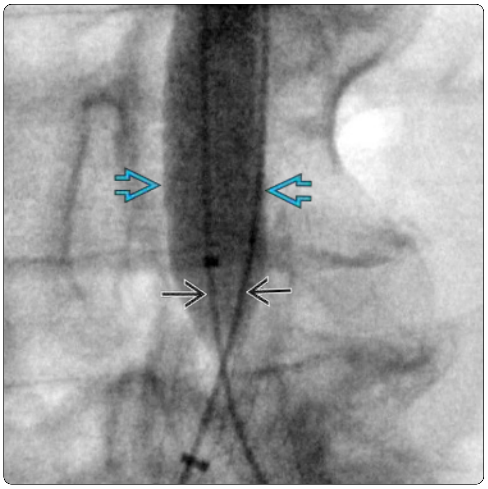


CERAB Revascularization Technique: Initial Aortic & Pelvic Angiography

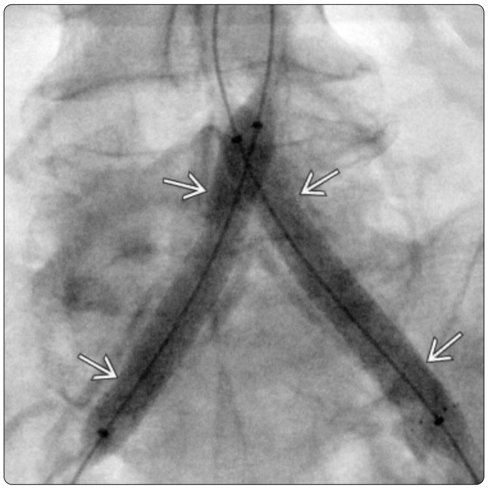


(Left) *A 67-year-old man had a noninvasive imaging study that was consistent with aortoiliac disease as the etiology of his severe bilateral buttock & thigh claudication, with accompanying impotence (Leriche syndrome). CECT shows extensive calcification → in this distribution.* **(Right)** *DSA of the distal aorta & pelvis confirms severe & irregular bilateral CIA stenoses ↪ & a narrowed distal aorta ⇨. Endovascular reconstruction of the aortic bifurcation was felt to be the best treatment option for this patient.*

CERAB Revascularization Technique: Placement of Distal Aortic Covered Stent

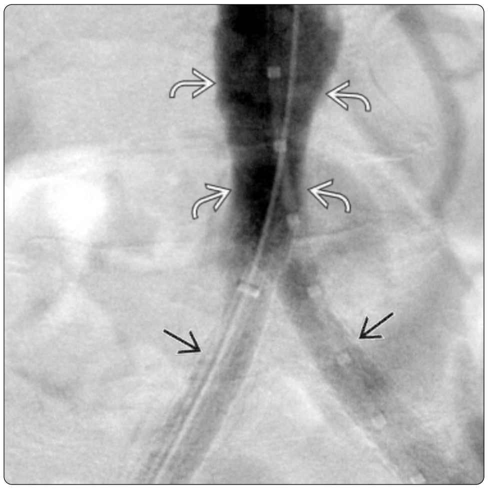


CERAB Revascularization Technique: Placement of Iliac Artery Covered Stents

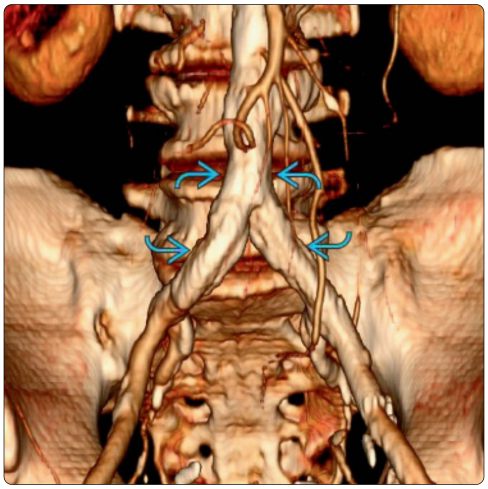


(Left) *After the crossing of the CIA stenoses with guidewires →, a large-caliber covered stent was placed in the distal aorta. It was gently distended with a compliant balloon ⇨ so that the stent configured to the aorta & tapered distally toward the bifurcation.* **(Right)** *Covered stents were then introduced & placed across the bilateral CIA stenoses. They were positioned so that they extended into the lower portion of the covered aortic stent & then were distended with angioplasty balloons →.*

CERAB Revascularization Technique: Completion Angiography After Treatment



CERAB Revascularization Technique: CECT Surveillance Imaging After Treatment



(Left) *After endovascular reconstruction of the aortic bifurcation, a completion DSA of the treatment zone was performed. This demonstrates that the aorta tapers ↪ in normal fashion toward the bifurcation & that the CIAs → are now widely patent. This now closely approximates the appearance of a normal native aortic bifurcation.* **(Right)** *A 3D CTA of the distal aorta & iliac arteries shows a normal configuration to the aortic bifurcation ↪. With the heavy calcification, it is difficult to clearly see the stents.*

Pelvic Arteries: Exclusion

KEY FACTS

TERMINOLOGY

- **Iliac artery aneurysm (IAA)**: Abnormal arterial enlargement of ≥ 50% of normal vessel diameter
    - Most IAAs associated with abdominal aortic aneurysms
- **Hemodynamically unstable pelvic fracture**: Systolic blood pressure < 90 mm Hg with associated pelvic fracture
    - Transcatheter embolization indicated for persistent hemodynamic instability despite pelvic stabilization

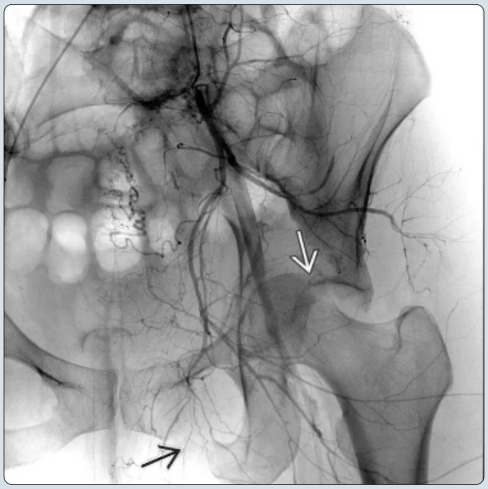
PROCEDURE

- IAA
    - Treatment depends on IAA location/morphology
    - Distal extent of IAA has most impact on treatment
    - If adequate distal seal zone, endograft can terminate in distal common iliac artery
    - If common IAA extends to iliac bifurcation, can place flared graft limb to iliac bifurcation level
    - Internal IAA or iliac bifurcation > 25 mm in diameter requires additional intervention
        - May require coil embolization of internal IAA or of distal internal iliac artery branches
        - Branch graft technology available for preserving internal iliac artery perfusion
- **Hemodynamically unstable pelvic fracture**
    - Contrast extravasation identified on CECT may suggest/localize most likely arterial source
    - Catheterize suspected artery, obtain DSA
    - If contrast extravasation identified on DSA, perform superselective catheterization; embolize
        - Possible embolic agents may include coils, permanent particles, or Gelfoam slurry
    - If no contrast extravasation on DSA, perform nonselective internal iliac artery embolization
        - Gelfoam slurry is typically embolic agent of choice

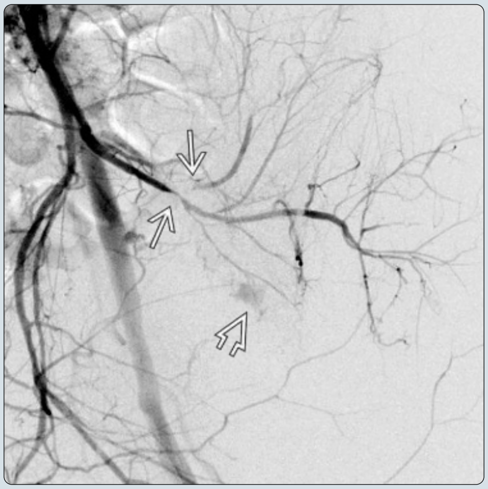
OUTCOMES

- Transcatheter embolization 85-97% effective in controlling hemorrhage from pelvic arterial source

Exclusion of Internal Iliac Arterial Injury Sustained During Pelvic Trauma

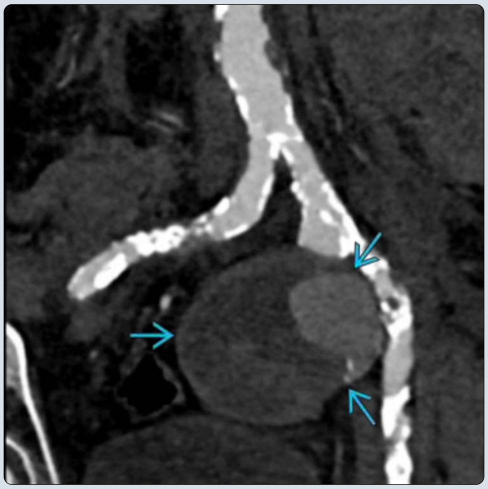


Exclusion of Internal Iliac Arterial Injury Sustained During Pelvic Trauma

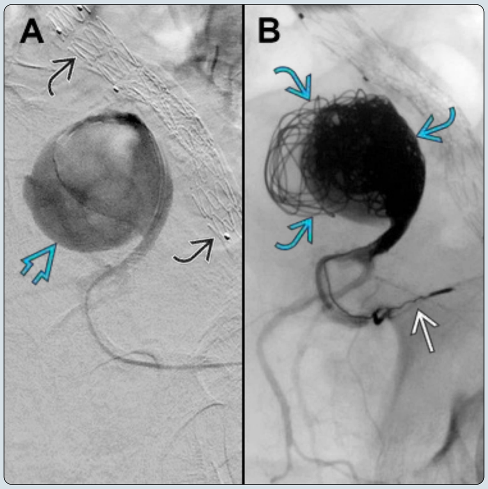


(Left) *Native DSA image was obtained during emergency left iliac artery angiography in a patient who sustained blunt pelvic trauma during a motor vehicle accident and then presented with hypotension. There are displaced left acetabular ➡ and inferior pubic ramus → fractures.* **(Right)** *Left common iliac artery DSA shows focal contrast extravasation ⇨ arising from the superior gluteal artery, as well as vasospasm ➡. The bleeding was controlled with Gelfoam embolization of the superior gluteal artery.*

Direct Percutaneous Treatment of Large Left Internal Iliac Artery Aneurysm



Direct Percutaneous Treatment of Large Left Internal Iliac Artery Aneurysm



(Left) *CECT MIP shows an extremely large left internal iliac artery aneurysm →. This aneurysm was initially treated by placing a covered stent across the origin of the internal iliac artery so as to eliminate inflow and induce thrombosis of the aneurysm.* **(Right)** *(A) Despite placement of a covered stent ↪, the aneurysm ⇨ remained patent and was now inaccessible for transcatheter embolization. (B) Coils ↪ were deployed into the aneurysm via direct percutaneous access ➡, and this treatment successfully thrombosed the aneurysm sac.*

Pelvic Arteries: Exclusion

TERMINOLOGY

Definitions

- **Iliac artery aneurysm (IAA)**: Abnormal arterial enlargement of ≥ 50% of normal vessel diameter
    - Common iliac artery (CIA) aneurysm defined as transverse diameter > 1.5 cm
        - Most IAAs associated with abdominal aortic aneurysms (AAA)
            - Iliac aneurysms present in roughly 20% of AAA
        - Isolated IAAs uncommon
            - 1-2% of all abdominal aneurysmal disease
    - Internal IAAs rare (≤ 0.4%)
        - Typically associated with aortic/CIA aneurysms
    - External IAAs exceedingly rare
- **Hemodynamically unstable pelvic fracture**: Persistent systolic blood pressure < 90 mm Hg with associated pelvic fracture
    - Hemorrhage severity classified according to American College of Surgeons Advanced Trauma Life Support
        - Class I: Involves up to 15% of blood volume
        - Class II: Involves 15-30% of total blood volume
            - Tachycardia, peripheral vasoconstriction, pallor
            - Typically responds to volume resuscitation
        - Class III: 30-40% loss of circulating blood volume
            - Hypotension, peripheral hypoperfusion (shock)
            - Requires volume resuscitation and blood products
        - Class IV: Loss of > 40% of circulating blood volume
            - Requires aggressive resuscitation to avoid death
    - Class III-IV patients with pelvic ring disruption need immediate pelvic stabilization with external fixation
        - Continuing blood loss despite fracture stabilization and aggressive resuscitation mandates angiography to look for arterial bleeding source
            - May require transcatheter embolization; typically performed in lieu of surgical exploration
            - Embolization avoids contamination associated with operative ligation of bleeding vessels; preserves tamponade effect in retroperitoneum

Pertinent Pelvic Vascular Anatomy

- **CIA**: Origin at aortic bifurcation; divides into external and internal iliac arteries
    - Typically 4-6 cm long; ≥ 1 cm in diameter
    - Extraperitoneal inferolateral course along medial psoas muscle margin; bifurcates at pelvic brim
- **External iliac artery**: Extends from CIA bifurcation to inguinal ligament
    - Typically 8-10 cm long; 6-8 mm in diameter
    - Anteroinferior course along psoas muscle medially
    - Gives origin to 2 major branches
        - **Inferior epigastric artery**
            - Arises immediately above inguinal ligament; cephalad course deep to rectus abdominis
            - Anastomoses with superior epigastric artery (continuation of internal mammary artery)
            - May give rise to obturator/accessory obturator artery (anatomic variant seen in 30%)
        - **Deep circumflex iliac artery**
            - Courses along iliac crest of pelvis
            - Anastomoses with iliolumbar/superior gluteal artery; important collateral in iliac occlusions
- **Internal iliac (hypogastric) artery**: Originates at CIA bifurcation; divides into 2 trunks
    - Anterior division branches
        - **Obturator artery**: Courses to obturator foramen; divides into anterior and posterior branches
        - **Inferior gluteal artery**: Largest anterior division branch; supplies buttock/posterior thigh
        - **Umbilical artery**: Patent part of embryonic umbilical artery; gives off 2 branches
            - **Superior vesical artery**: Supplies upper urinary bladder; may give rise to ductus deferens artery
            - **Ductus deferens artery**: Supplies vas deferens; accompanies into scrotum and testis
        - **Uterine artery**: Supplies uterus; courses in cardinal ligament (base of broad ligament)
        - **Inferior vesical artery**: Supplies lower urinary bladder; also seminal vesicles/prostate in male patients
        - **Vaginal artery**: Supplies vagina, bladder base, lower rectum; may arise from uterine artery
        - **Middle rectal artery**: Usually arises with inferior vesical artery; supplies rectum
        - **Internal pudendal artery**: Supplies perineum/external genitalia; multiple branches
            - **Inferior rectal artery**: Supplies anus; anastomoses with middle superior rectal arteries
            - **Perineal artery**: Supplies perineal muscles; posterior aspect of scrotum
            - **Dorsal penile (clitoral) artery**: Together with bulbourethral artery supplies penis/clitoris
    - Posterior division arterial branches
        - **Iliolumbar artery**: 1st branch of posterior division; supplies psoas/iliacus muscles
        - **Superior gluteal artery**: Largest branch of internal iliac artery; supplies gluteal muscles
        - **Lateral sacral artery**: Supplies erector spinae/pyriformis muscles; contents of sacral canal

PREPROCEDURE

Indications

- CIA aneurysm
    - Diameter > 3 cm
        - No reported ruptures in aneurysms < 3 cm
- Internal IAA
    - No definite size criteria consensus
        - Treatment recommended if ≥ 3 cm
    - Reported 26% rupture rate in single series
        - Failed to establish statistically significant correlation between lesion diameter and rupture risk
- Internal iliac artery exclusion prior to/during endovascular repair of CIA aneurysm that involves iliac bifurcation/extension into external iliac artery
    - Prevents retrograde perfusion of CIA aneurysm
    - Prefer to preserve internal iliac artery patency
        - Requires branched device use/bypass
        - Avoids buttock claudication/other complications
- Active hemorrhage from pelvic arterial source
    - Various causes
        - Hemodynamically unstable pelvic fracture

  - Transcatheter embolization for hemodynamic instability despite adequate pelvic stabilization
  - Transcatheter embolization for identified bleeding source, unless successful resuscitation
- Iatrogenic injury
  - Pelvic arteries susceptible to injury during gynecologic, orthopedic, endovascular procedures
- Inflammatory process
- Neoplasm
  - Tumor encasement of pelvic arteries may eventually cause erosion and breach of arterial wall integrity with resultant hemorrhage

Contraindications

- Anaphylaxis to iodinated contrast medium
- Renal insufficiency
- Uncorrectable coagulopathy

Preprocedure Imaging

- US
  - **F**ocused **a**ssessment with **s**onography for **t**rauma (FAST) for initial screening in pelvic trauma
    - Used in hemodynamically unstable pelvic fractures to evaluate for active intraperitoneal bleeding
      - 87-100% specificity but poor (26%) sensitivity in presence of unstable pelvic fracture
- CTA
  - Excellent delineation of arterial anatomy/pathology
    - Characterization of target lesion(s)
    - Preprocedural planning for intervention
  - CECT recommended to evaluate for intraabdominal bleeding in hemodynamically stable patient with pelvic fracture regardless of FAST results
    - Excellent for excluding pelvic hemorrhage
    - Absence of contrast extravasation on CT does not always exclude active hemorrhage
- MRA
  - Excellent delineation of arterial anatomy/pathology
    - Contrast and noncontrast techniques available
- DSA
  - Provides imaging guidance during intervention

Getting Started

- Things to check
  - Clinical history and physical examination
    - Appropriate procedure indications
    - Comprehensive cardiovascular evaluation
      - Detailed pulse examination/Doppler evaluation
    - Current medications
      - Any anticoagulants/antiplatelet agents
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - CBC
      - Platelet count > 50,000/μL
    - Coagulation profile
      - INR ≤ 1.5
      - Normal PT, PTT
  - Limit oral intake: NPO for 8 days prior to procedure
    - If moderate sedation/general anesthesia planned
    - Take any oral medications with water sip
  - Informed procedural and sedation consent obtained
- Medications
  - Agents for moderate sedation
    - Fentanyl
    - Midazolam
  - Vasodilator (e.g., nitroglycerin)
    - Typical bolus dose of 100 μg nitroglycerin
    - Prevents/treats catheter-induced vasospasm
  - 1-2% lidocaine local anesthesia
- Equipment list
  - Access sheaths
    - 5- to 8-Fr vascular access sheath
      - Size depends on catheters/delivery systems
      - Permits catheter exchanges as necessary
    - Crossover access sheath (for contralateral access)
      - e.g., Ansel, Balkin sheaths
  - Catheters
    - Diagnostic catheter
      - Flush (e.g., pigtail, OmniFlush) catheter
    - Selective catheter
      - Hydrophilic straight/angled catheter
      - May use to direct guidewire into target artery
    - Coaxial 2.6- to 3.0-Fr microcatheter
      - Various proprietary options
  - Guidewires
    - Initial "starting" 0.035" guidewire
    - Angled or straight-tipped hydrophilic guidewire
      - Often beneficial for selective catheterization
    - Stiff guidewire (e.g., Amplatz, Rosen)
      - Stability when advancing/placing devices
    - 0.014-0.018" microwire
      - For use with microcatheter
  - Embolic agents
    - Coils
      - Detachable 0.035" or 0.018" embolization coils
      - "Pushable" 0.035" or 0.018" embolization coils
    - Liquids
      - N-butyl cyanoacrylate (n-BCA) TRUFILL (Cordis; Bridgewater, NJ)
      - Onyx: (ev3 Neurovascular; Irvine, CA)
      - Thrombin: Activates coagulation cascade
    - Gelfoam (Upjohn; Kalamazoo, MI)
      - Sheet form; can cut into pledgets/create slurry
      - Temporary embolic agent
    - Particles
      - Lodge at precapillary/capillary level; occlude vessels/devascularize tissue
      - Various sizes, compositions
    - Plug occluding device
      - Amplatzer vascular plug (AGA Medical; North Plymouth, MN)
  - Stents
    - Noncovered self-expanding/balloon mounted
      - May be used for stent-assisted coiling
    - Covered self-expanding/balloon mounted
      - May be used for arterial exclusion

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Typically common femoral artery access
    - Access may be ipsilateral/contralateral to target
      - Determined by location of target for exclusion
  - Radial artery access may be useful in cases of hemodynamically unstable pelvic fracture
    - Pelvic external fixation device may sometimes make transfemoral arterial access problematic

Procedure Steps

- **General**
  - Sterilely prepare/drape intended access site
  - Administer 1-2% lidocaine local anesthesia
  - Obtain arterial access; insert access sheath
  - Introduce flush/selective catheter via sheath
  - Position catheter for initial DSA imaging
    - e.g., pigtail catheter in distal aorta for pelvic DSA
  - Inject contrast; obtain DSA images
    - Review DSA, determine appropriate intervention
  - Proceed to more selective catheterization as needed
    - May use reverse-curve catheter/crossover sheath to gain access to contralateral CIA
      - If access to contralateral internal iliac artery needed, use Cobra catheter afterward
      - For access to ipsilateral internal iliac artery, use reverse-curve catheter or form Waltman loop
    - Consider coaxial microcatheter if selectively catheterizing internal iliac artery branches
  - Confirm catheter tip position with DSA prior to any transcatheter intervention
    - If satisfactory, proceed with intervention
      - Monitor fluoroscopically during treatment
  - Following intervention obtain DSA
    - Document results/exclude complications
- **IAAs**
  - Treatment depends on IAA location/morphology
    - Need 10-15 mm of normal arterial diameter neck above and below aneurysm for seal zones
  - IAA usually treated proximally with bifurcated aortic endograft because most have associated AAA
    - Isolated IAA with good proximal and distal necks occasionally treated with "tube" endograft
  - Distal component of aneurysm typically impacts treatment choice to greatest extent
    - If adequate distal seal zone (e.g., common IAA does not extend to iliac bifurcation), endograft can terminate in distal CIA
    - If common IAA extends to iliac bifurcation, can place flared graft limb to iliac bifurcation level
      - Requires distal aneurysm diameter ≤ 25 mm
    - Internal IAA or iliac bifurcation > 25 mm in diameter requires additional intervention
      - Coil/plug occlusion of internal iliac artery to prevent retrograde perfusion of aneurysm with graft extension into external iliac artery
      - Use of bifurcated side branch iliac endograft to preserve internal iliac artery perfusion
      - Use of surgical internal iliac artery bypass with graft extension into external iliac artery
- **Hemodynamically unstable pelvic fracture**
  - Contrast extravasation identified on CECT may suggest/localize most likely arterial source
  - Catheterize target artery (e.g., internal iliac artery)
    - Inject contrast; obtain DSA
  - If contrast extravasation identified on DSA
    - Perform superselective catheterization of arterial bleeding source; consider coaxial microcatheter
    - Advance microcatheter beyond extravasation site
      - Perform distal to proximal coil embolization
    - If microcatheter cannot be placed distal to injury
      - Consider embolization with Gelfoam slurry vs. proximal coil placement
  - If no contrast extravasation identified on DSA
    - Perform nonselective internal iliac artery embolization if ongoing hemodynamic instability
      - Use temporary agent (e.g., Gelfoam slurry)
      - May require bilateral embolization if unable to localize potential bleeding site
- **Pelvic arterial bleeding (other causes)**
  - If focal arterial injury identified on DSA, analyze images, determine most appropriate treatment
    - Embolization vs. covered stent placement
  - If embolization indicated, choose optimal agent
    - Temporary vs. permanent agent
  - If covered stent indicated, choose appropriate size
    - Stent diameter should be slightly larger than native artery
    - Stent ends should extend sufficiently beyond lesion proximally and distally
  - Place covered stent
    - Obtain DSA after stent placement to confirm satisfactory stent position, exclusion of lesion

Alternative Procedures/Therapies

- Radiologic
  - Direct percutaneous access of aneurysm or pseudoaneurysm
    - May be used to successfully treat aneurysms or pseudoaneurysms of internal iliac artery or branches that are inaccessible for transcatheter embolization
      - Embolization using coils or liquid agents (e.g., n-BCA, onyx) directly introduced via percutaneous tract
- Surgical
  - Open surgical repair of IAA
    - Higher morbidity/mortality than endovascular aneurysm repair (EVAR)
  - Extraperitoneal pelvic packing in hemodynamically unstable pelvic fracture
    - Safe/quick way to enhance/stabilize hemodynamics
      - Reduces acute hemorrhage-related mortality when used in combination with optimal fluid resuscitation/transfusion
      - May be useful bridge to transcatheter embolization
  - Internal iliac artery surgical ligation in hemodynamically unstable pelvic fracture
    - Reports of bladder, gluteal, rectal, and scrotal necrosis

  - Resuscitative endovascular balloon occlusion of aorta (REBOA)
    - Adjunct to trauma hemorrhage control; intravascular balloon placement provides early aortic occlusion
      - Used to improve blood pressure/stabilize patients to undergo definitive hemorrhage control
    - Main indications for use in trauma
      - Hemorrhagic shock related to pelvic bleeding
      - Abdominal/torso hemorrhage
    - REBOA deployment for pelvic hemorrhage
      - Aortic zone III (from lowest renal artery to aortic bifurcation)

POST PROCEDURE

Things to Do

- Obtain routine scheduled surveillance CECT imaging after treatment of IAAs
  - Same imaging protocol as for aortic aneurysm EVAR
- Closely monitor hemodynamics after embolization for active hemorrhage from pelvic arterial source
  - Patient may require additional fluids/blood products despite lack of continued bleeding
    - Due to fluid shifts from volume resuscitation
  - If hemodynamic destabilization, obtain abdominal/pelvic CECT to exclude recurrent bleeding
    - May require repeat transcatheter embolization

OUTCOMES

Complications

- Most feared complication(s)
  - **IAA endovascular repair**
    - With associated internal iliac artery embolization
      - Buttock claudication reported in up to 35%
      - Erectile dysfunction reported in up to 17%
      - Gluteal necrosis, colonic ischemia also reported
  - **Nonselective internal iliac artery embolization**
    - Distal tissue ischemia/necrosis
      - Isolated cases of bladder, femoral head necrosis
      - Random cases of gluteal muscle necrosis
    - Recurrent hemorrhage after initial clinically successful embolization
      - Reversal of shock-induced vasoconstriction may allow reperfusion of arterial injury site if embolic agent undersized/migrates distally
      - May require repeat embolization
    - Nontarget embolization
- Immediate/periprocedural complication(s)
  - Arterial dissection/thrombosis
  - Access site complications
    - Hematoma, pseudoaneurysm, iatrogenic arteriovenous fistula formation
  - Allergic/anaphylactic reaction to contrast
  - Contrast-induced nephropathy
- Delayed complication(s)
  - **IAA endovascular repair**
    - Endoleak requiring intervention
    - Endograft limb thrombosis (1-5% incidence)
    - Endograft infection (0.5-1.0% incidence)

Expected Outcome

- Very high technical and clinical success in EVAR exclusion of IAAs
  - 80-96% reported 2-year patency rates
- Transcatheter embolization 85-97% effective in controlling hemorrhage from pelvic arterial source
  - Recent data compared outcomes in trauma patients with active bleeding treated with exploratory laparotomy and surgical packing vs. embolization
    - Surgical group had significantly increased 30-day mortality

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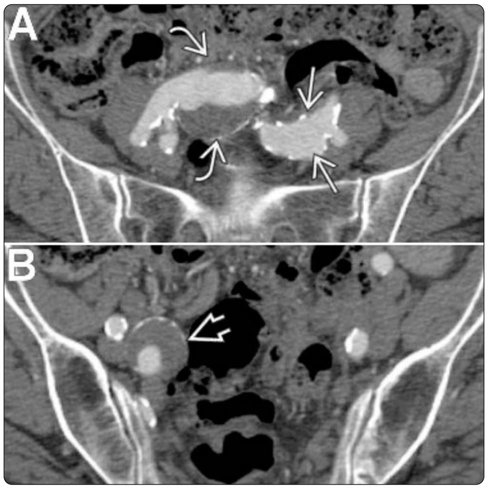
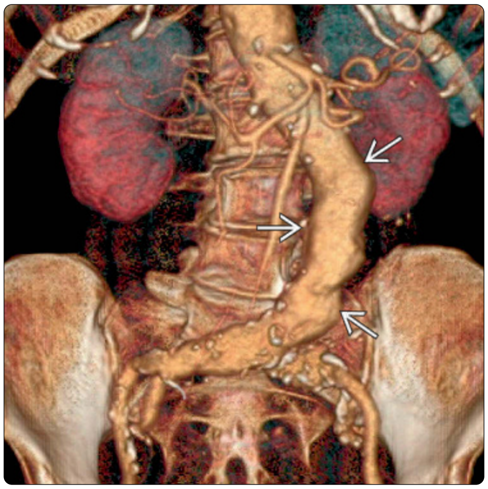
Iliac Artery Aneurysm Exclusion: Initial CECT Evaluation

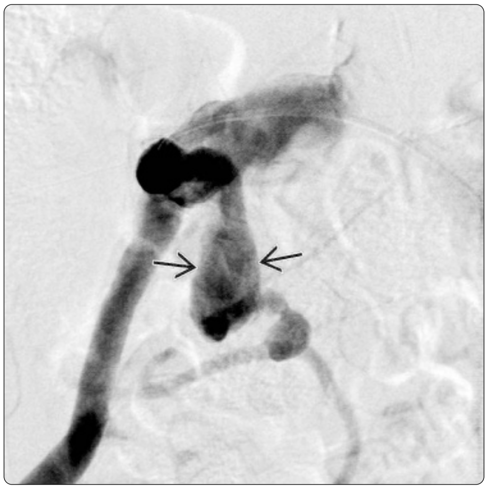


Iliac Artery Aneurysm Exclusion: Initial 3D CTA Reformation

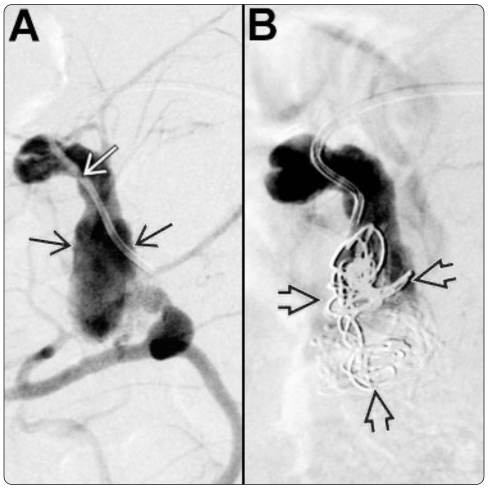


(Left) *(A) Axial CECT just below the aortic bifurcation shows a large, thrombus-containing right common iliac artery aneurysm ↪. A smaller aneurysm involves the left common iliac artery →. (B) More distally, there is a large right internal iliac artery aneurysm ⇨, which also contains laminar thrombus.* **(Right)** *Coronal 3D reformation shows that an abdominal aortic aneurysm (AAA) → is associated with the iliac artery aneurysms. Iliac artery aneurysms are present in ~ 20% of patients in whom an AAA is found.*

Iliac Artery Aneurysm Exclusion: Right Iliac Artery Aneurysms on DSA

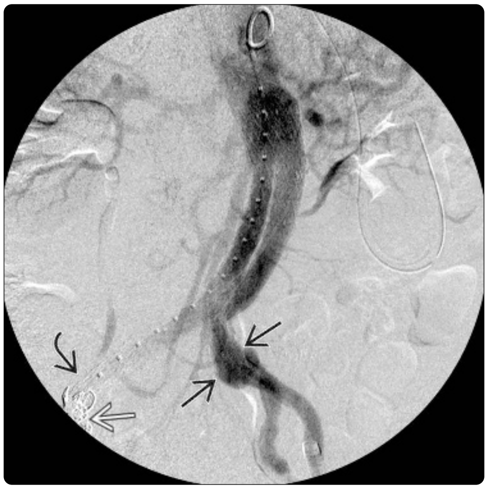


Iliac Artery Aneurysm Exclusion: Internal Iliac Artery Coil Embolization

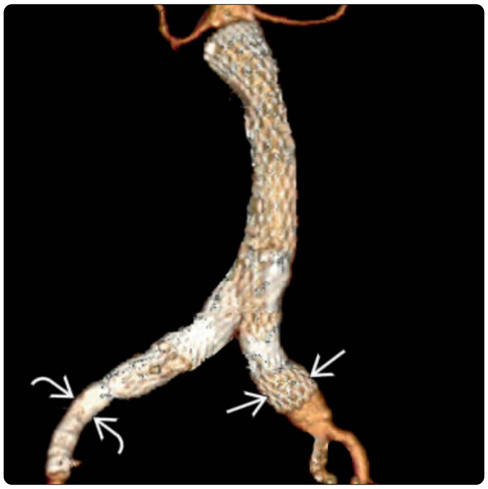


(Left) *As isolated iliac artery aneurysms are rare, endovascular treatment usually involves concurrent AAA repair. This patient required treatment of the right internal iliac artery aneurysm → seen on this DSA, prior to EVAR of the common iliac and aortic aneurysms.* **(Right)** *(A) A catheter → was placed in the internal iliac artery aneurysm → from a contralateral approach, and (B) embolization coils ⇨ were used to occlude the aneurysm, thus preventing retrograde perfusion from distal internal iliac branches.*

Iliac Artery Aneurysm Exclusion: EVAR of Aortoiliac Aneurysms



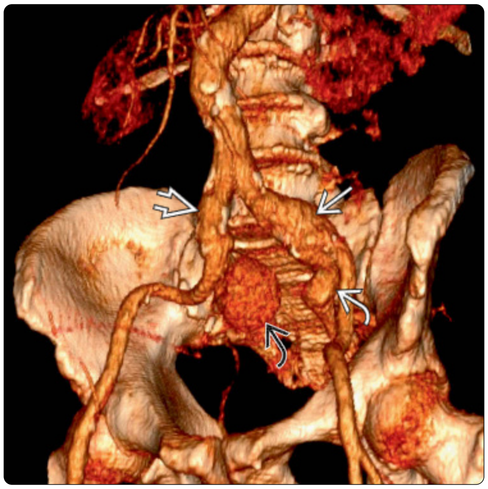
Iliac Artery Aneurysm Exclusion: Post-EVAR Surveillance CTA



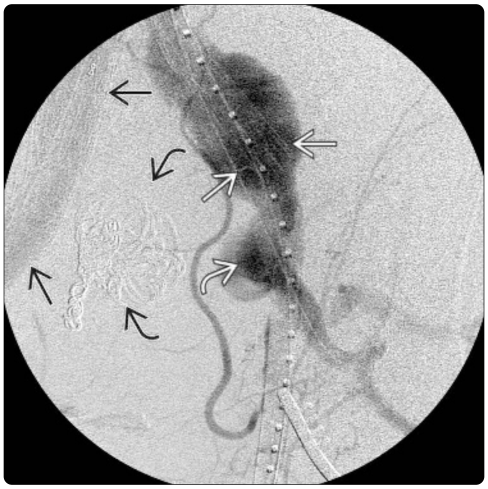
(Left) *DSA during EVAR shows an endograft, with the distal left limb → flaring within the common iliac artery aneurysm & the right limb ↪ extending into the external iliac artery along with the embolization coils ⇨.* **(Right)** *Post-EVAR CTA shows the flared left iliac limb → & the right limb extension ↪ into the external iliac artery. Common iliac artery aneurysms involving the iliac bifurcation may be treated with flared limbs if an appropriately sized endograft is chosen. The seal with larger aneurysm diameters is sometimes problematic.*

(Left) *CTA shows large left ➡ and small right ⇨ common iliac artery aneurysms and bilateral internal iliac artery aneurysms; the right-sided aneurysm ↪ is saccular, and the left ↷ is fusiform.* **(Right)** *The right internal iliac artery aneurysm was coil embolized, and a covered stent was placed in the common iliac artery. DSA shows coils ↪, the right iliac stent →, and the distal end of a bifurcated endograft ➡ ending in the left common iliac artery aneurysm. The left internal iliac artery aneurysm ↷ is well seen.*

Internal Iliac Aneurysm Exclusion: Initial 3D CTA Reformation

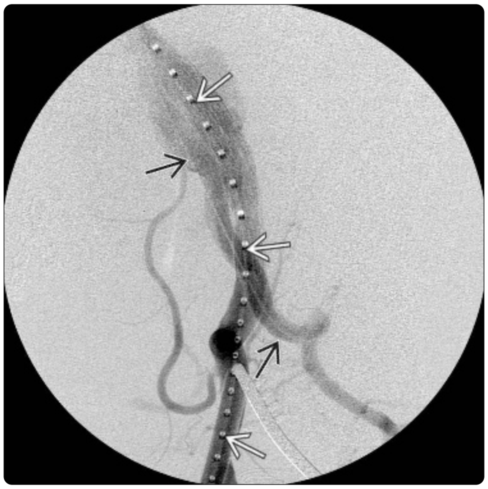


Internal Iliac Aneurysm Exclusion: Associated Common Iliac Aneurysm

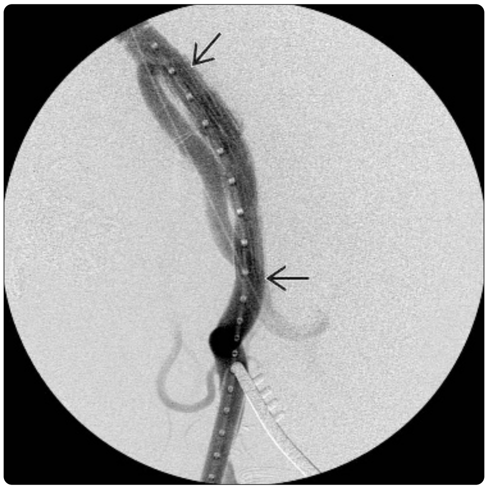


(Left) *Via transbrachial access, a guidewire → was placed distally in the left internal iliac artery. A covered stent was then placed with the distal end terminating beyond the lowest extent of the internal iliac artery aneurysm, excluding the aneurysm while preserving perfusion. The calibrated catheter ➡ enters via a transfemoral artery access.* **(Right)** *An iliac limb → has been extended from the common iliac artery limb of the endograft into the external iliac artery, excluding the distal extent of the common iliac artery aneurysm.*

Internal Iliac Aneurysm Exclusion: Preservation of Internal Iliac Perfusion

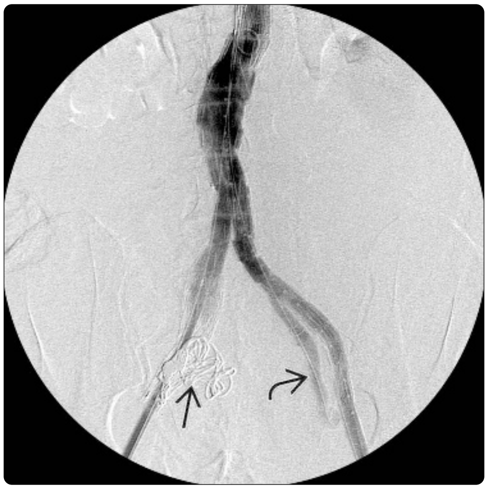


Internal Iliac Aneurysm Exclusion: Preservation of Internal Iliac Perfusion

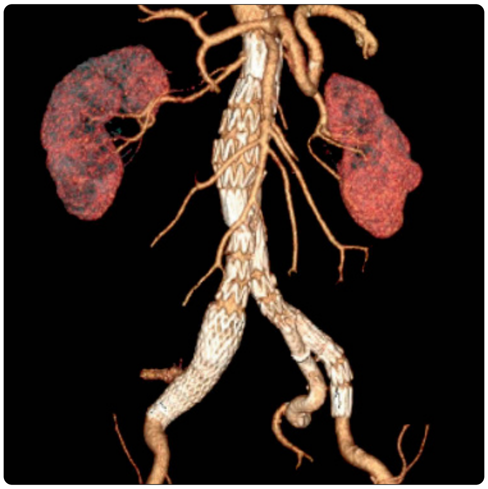


(Left) *DSA after EVAR using branched technology to treat the left common and internal iliac artery aneurysms shows preserved flow to the left internal iliac arterial territory ↪. Embolization coils → have occluded the right internal iliac artery aneurysm but have also eliminated arterial perfusion. Preserving left internal iliac perfusion reduces the possibility of buttock claudication.* **(Right)** *CTA shows endograft components, normally perfused native vasculature, and no endoleak. The aneurysms have been successfully excluded.*

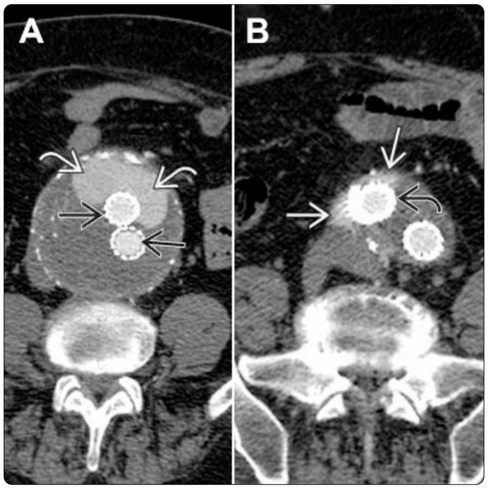
Internal Iliac Aneurysm Exclusion: DSA Following Aortoiliac EVAR



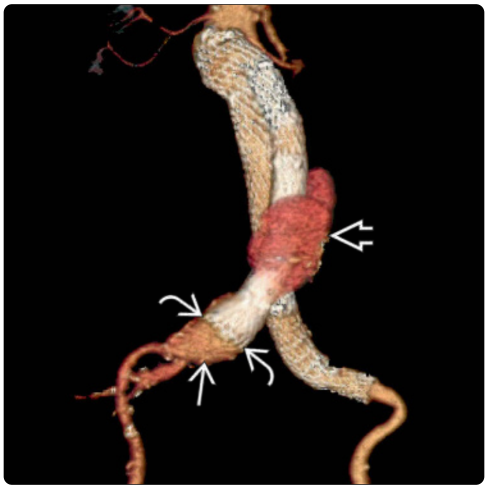
Internal Iliac Aneurysm Exclusion: Post-EVAR 3D CTA Reformation



Endoleak After Aortoiliac EVAR: Post-EVAR Surveillance CECT

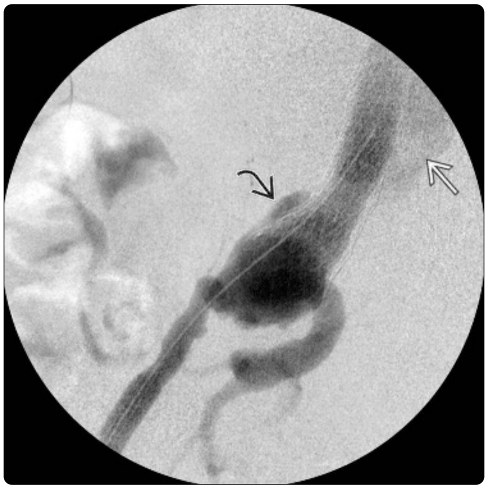


Endoleak After Aortoiliac EVAR: Post-EVAR 3D CTA Reformation

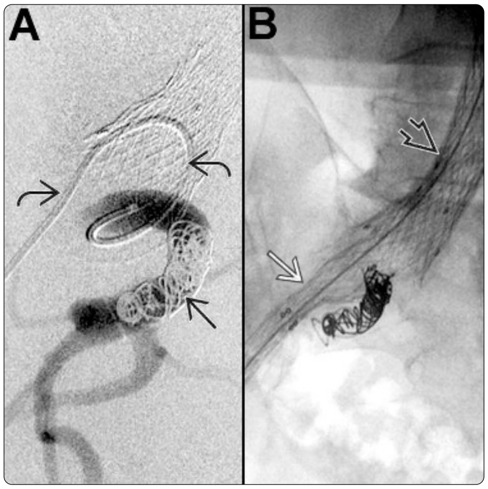


(Left) *CECT shows (A) an endoleak* ↪ *in the residual AAA sac after EVAR of aortic and right common iliac artery aneurysms. The endograft limbs* ⇨ *are seen in the sac. (B) Distally, the endoleak* ➡ *can be seen adjacent to the right iliac endograft limb* ↪*.* **(Right)** *CTA shows the large endoleak* ➡*. The right common iliac artery aneurysm had been treated using a flared distal endograft limb* ↪*, but this did not cover the lower extent* ➡ *of the aneurysm. A distal attachment endoleak (type IB) was suspected.*

Endoleak After Aortoiliac EVAR: DSA Evaluation of Endoleak

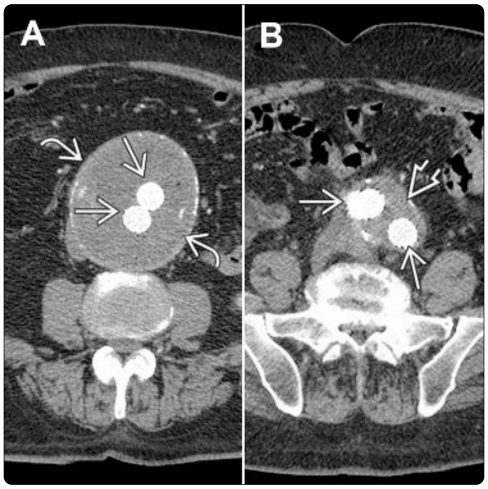


Endoleak After Aortoiliac EVAR: Type IB Endoleak Repair

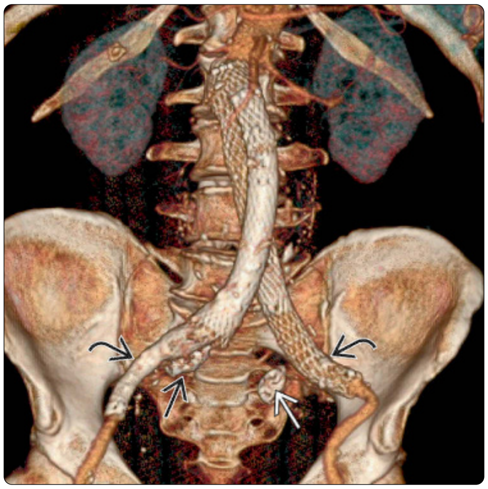


(Left) *DSA confirms a distal attachment type IB endoleak* ↪ *due to failure of the flared endograft limb to achieve a seal in the common iliac artery aneurysm. The endoleak* ➡ *extends into the AAA.* **(Right)** *(A) After placing a catheter* ↪ *in the right internal iliac artery, we used embolization coils* ⇨ *to occlude the artery in order to prevent retrograde perfusion of the common iliac artery aneurysm. (B) An endograft* ➡ *was extended from the flared limb* ⇨ *into the external iliac artery to exclude the common iliac artery aneurysm distally.*

Endoleak After Aortoiliac EVAR: CECT After Endoleak Repair



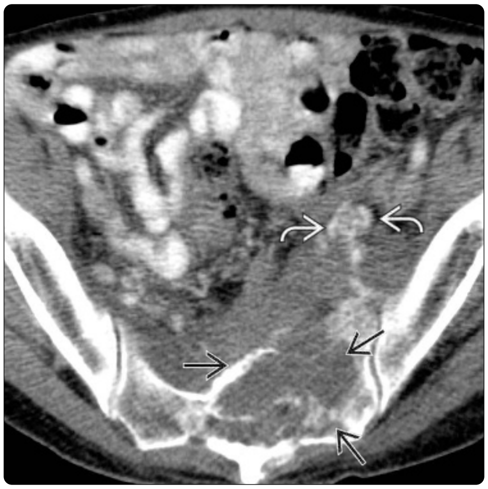
Endoleak After Aortoiliac EVAR: Post-Repair 3D CTA Reformation



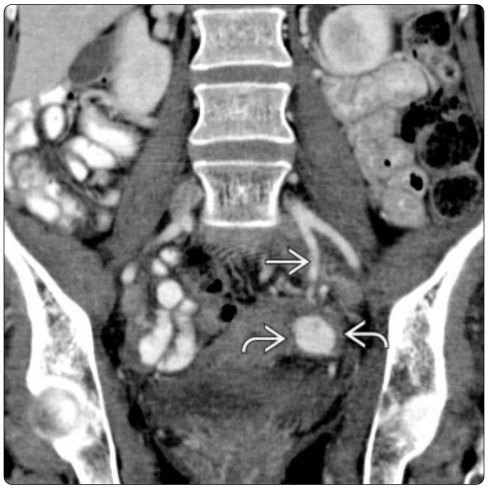
(Left) *Axial CECT at the level of (A) the AAA* ↪ *and (B) just above the aortic bifurcation* ➡ *shows that the previously identified endoleak is no longer present. The endograft limbs* ➡ *are opacified with contrast.* **(Right)** *Coronal 3D reformation shows embolization coils in the right* ⇨ *and left* ➡ *internal iliac artery territories. The iliac limbs* ↪ *of the bifurcated endograft extend bilaterally into the external iliac arteries. Unfortunately, the interrupted perfusion of the internal iliac arteries increases the risk of buttock claudication.*

(Left) *CECT in a man with metastatic rectal carcinoma and lower GI bleeding shows that a soft tissue mass has invaded and destroyed the left hemisacrum ⇨. There is a contrast collection ➡ within the mass that is suspicious for an arterial pseudoaneurysm.* **(Right)** *Coronal CECT shows the pseudoaneurysm ➡ to better advantage and also demonstrates that it most likely arises from the left internal iliac artery ➡. Although no extravasation is seen, the pseudoaneurysm is the most likely etiology for the lower GI hemorrhage.*

Internal Iliac Artery Pseudoaneurysm: Initial Pelvic CECT Evaluation

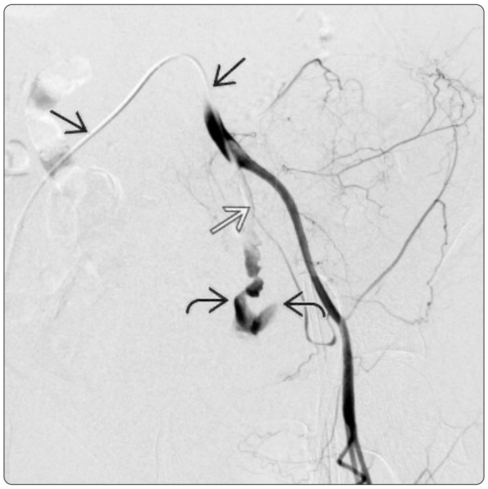


Internal Iliac Artery Pseudoaneurysm: Initial Pelvic CECT Evaluation

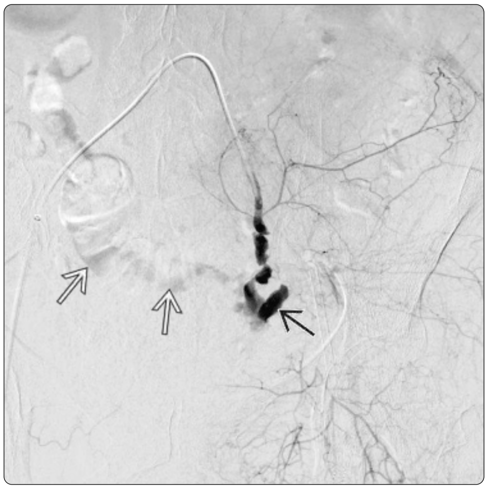


(Left) *DSA shows that a catheter ⇨ has been introduced on the right, and the tip ➡ has been placed in the proximal internal iliac artery near the vessel origin. There is an irregular contrast collection ⇨ arising from the internal iliac artery in the same distribution as the pseudoaneurysm seen on CECT.* **(Right)** *A delayed DSA image from the same internal iliac artery contrast injection shows communication of the pseudoaneurysm ⇨ with the bowel, as there is contrast ➡ entering and pooling within a small bowel loop.*

Internal Iliac Artery Pseudoaneurysm: Left Internal Iliac Artery DSA

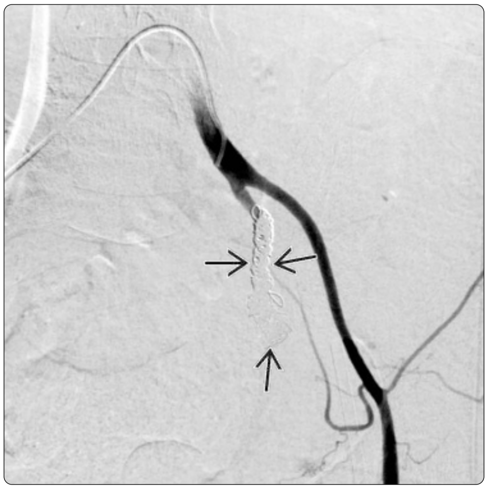


Internal Iliac Artery Pseudoaneurysm: Left Internal Iliac Artery DSA

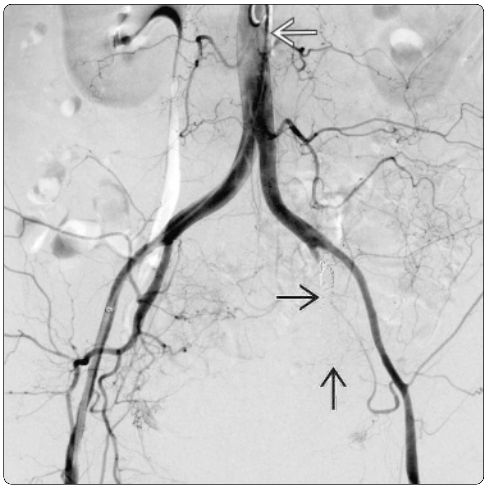


(Left) *The Cobra catheter tip was advanced distally and was placed within the pseudoaneurysm. Multiple embolization coils ⇨ were placed in the pseudoaneurysm and the main trunk of the internal iliac artery. DSA after embolization shows that there is no longer any filling of the pseudoaneurysm.* **(Right)** *After embolization, the selective catheter was replaced with a pigtail catheter ➡ that was placed in the distal aorta. DSA shows occlusion of the left internal iliac artery by the coils ⇨ and no abnormal contrast collections.*

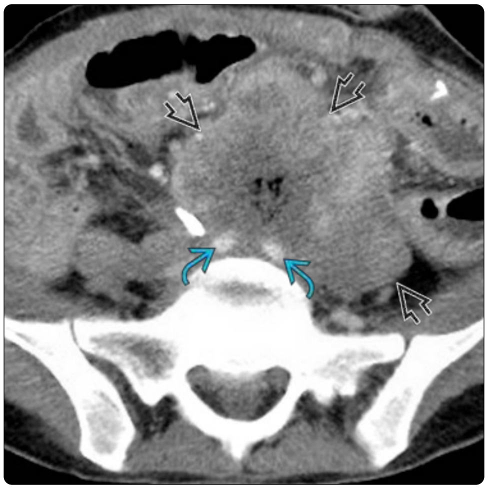
Internal Iliac Artery Pseudoaneurysm: Transcatheter Coil Embolization



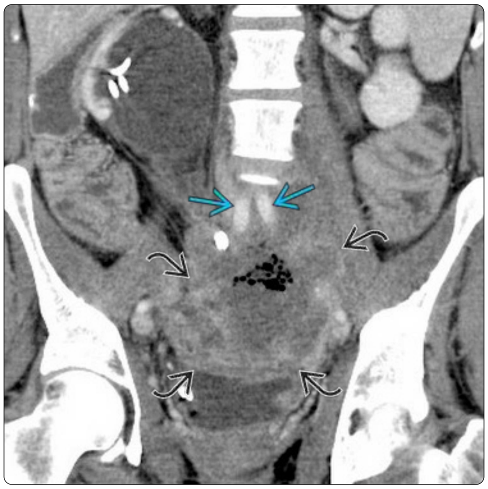
Internal Iliac Artery Pseudoaneurysm: Postembolization Pelvic DSA



Tumor Encasement of Iliac Arteries Causing GI Hemorrhage: CECT Evaluation

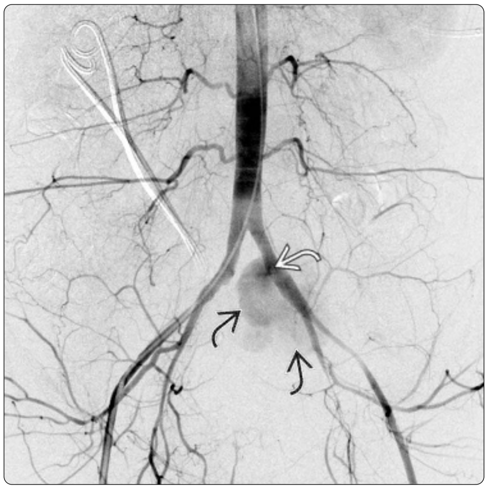


Tumor Encasement of Iliac Arteries Causing GI Hemorrhage: CECT Evaluation

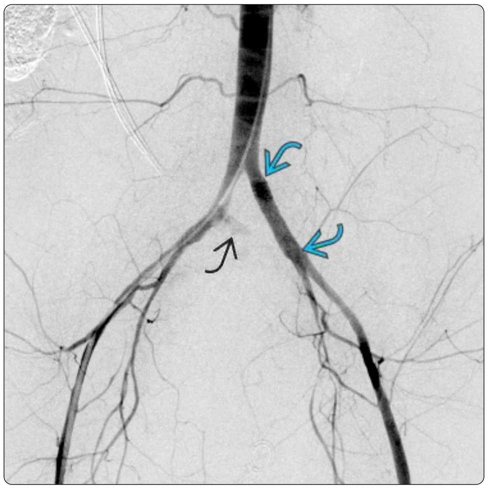


(Left) *A 58-year-old man with known extensive local recurrence of colon cancer presented with massive lower GI hemorrhage and hypotension. CECT shows a large necrotic tumor ⇨ encasing both common iliac arteries →.* **(Right)** *Coronal CECT image further demonstrates the extent of the tumor ⇨ that encases both common iliac arteries →. Breach of the arterial wall integrity from tumor erosion, with resultant bleeding into the colonic tumor mass, was felt to be the etiology for the lower GI hemorrhage.*

Tumor Encasement of Iliac Arteries: Erosion of Left Common Iliac Artery

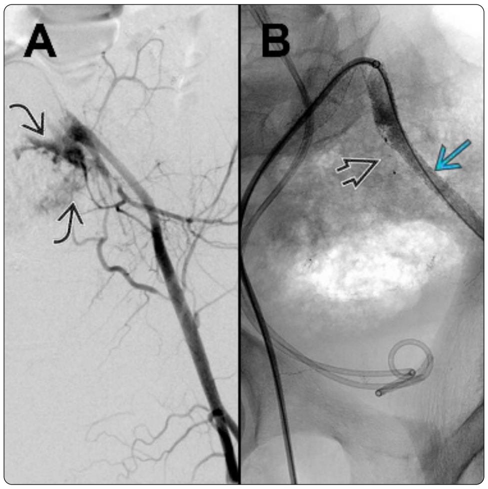


Tumor Encasement of Iliac Arteries: Erosion of Right Common Iliac Artery

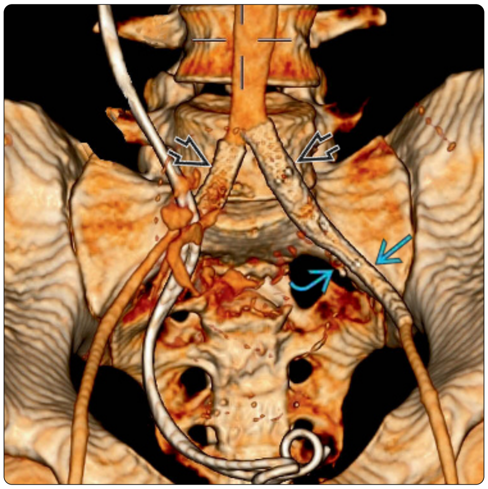


(Left) *The patient underwent emergency angiography. Pelvic arteriogram shows a jet ➡ of contrast exiting from the medial sidewall of the left common iliac artery and accumulating as a lobulated collection ⇨ that corresponds to the necrotic tumor mass.* **(Right)** *The left common iliac arterial defect was treated by placing a covered stent →. Two weeks later, the patient once again presented with lower GI hemorrhage. Repeat pelvic DSA shows that there is now a similar arterial wall defect and contrast extravasation ⇨ on the right.*

Tumor Encasement of Iliac Arteries: Erosion of Left Internal Iliac Artery



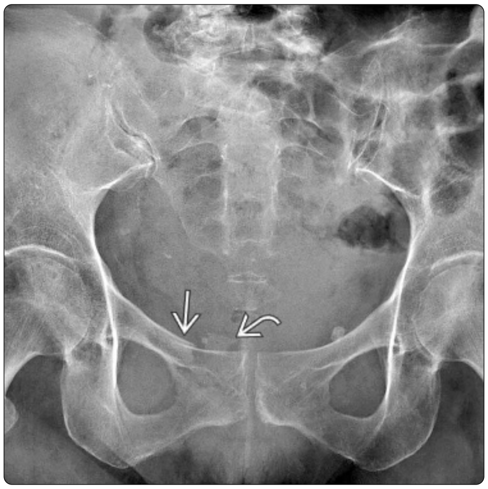
Tumor Encasement of Iliac Arteries: CTA After Covered Stents and Plug Occluder



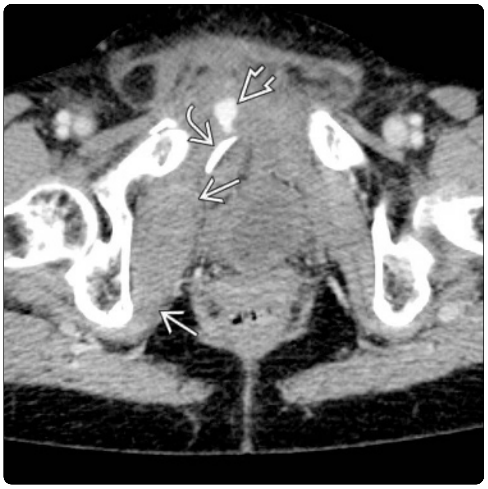
(Left) *After treatment with placement of the bilateral covered stents, the patient did well for 1 month but then again presented with lower GI bleeding. DSA shows (A) extravasation of contrast ⇨ from the internal iliac artery that was treated by (B) placing a plug occluder ⇨ in the internal iliac artery and extending a covered stent → into the external iliac artery.* **(Right)** *3D CTA shows the bilateral common ⇨ and left external iliac artery → stents and the plug occluder →. The patient later succumbed to his primary disease.*

(Left) *AP pelvic radiograph in a 79-year-old woman who presented to the ED with right hip pain & hypotension after falling shows a right superior pubic ramus fracture → with a displaced bone fragment ↪.* **(Right)** *The patient was sufficiently stable to undergo further imaging evaluation. Axial CECT shows the previously noted displaced fracture fragment ↪ with an adjacent, large, rounded contrast collection ⇨, felt to represent extravasation signifying active hemorrhage. A pelvic hematoma → displaces the urinary bladder.*

Hemodynamically Unstable Fracture: Initial Radiographic Imaging

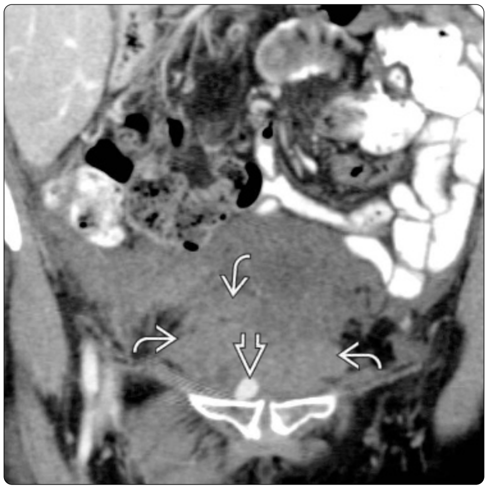


Hemodynamically Unstable Fracture: Initial Axial CECT Evaluation

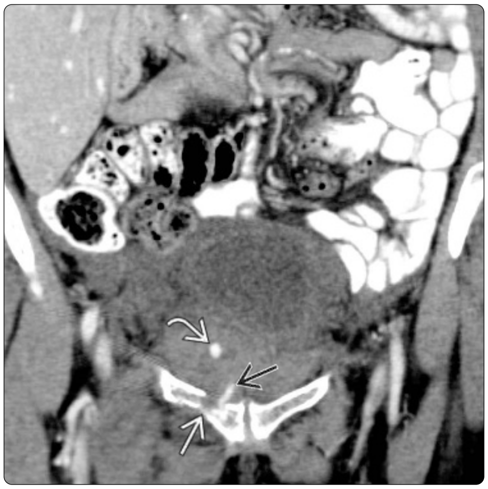


(Left) *Coronal CECT confirms the contrast collection ⇨ adjacent to the fractured superior pubic ramus & shows the large hematoma ↪ surrounding the area of contrast extravasation.* **(Right)** *More posterior CECT image better demonstrates the pubic ramus fracture → & shows a linear component ⇾ to the extravasated contrast collection. Additionally, there is a 2nd collection of extravasated contrast ↪ seen more superiorly within the pelvic hematoma. The findings suggest multiple bleeding sites.*

Hemodynamically Unstable Fracture: Coronal CECT Reconstruction

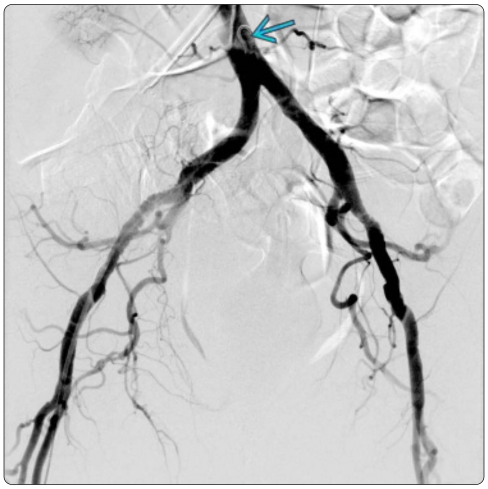


Hemodynamically Unstable Fracture: Coronal CECT Reconstruction

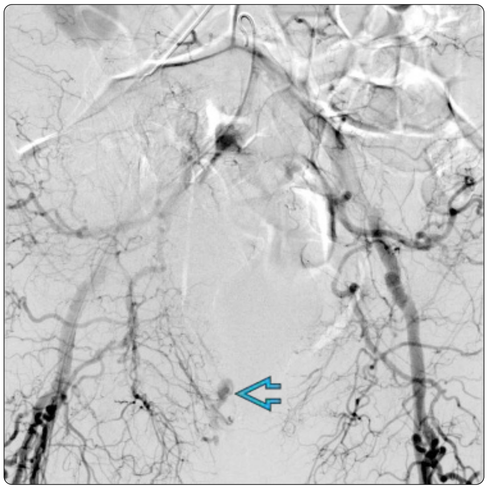


(Left) *Based on the CECT findings & continued hypotension, the patient underwent emergency angiography. Pelvic DSA via a flush catheter ⇾ positioned in the distal abdominal aorta fails to demonstrate contrast extravasation in this early arterial phase image.* **(Right)** *A more delayed image from the DSA arteriogram shows an irregular contrast collection ⇨ medially that appears to arise from branches of the right internal iliac artery. The position and configuration of the collection correlate well with the CT findings.*

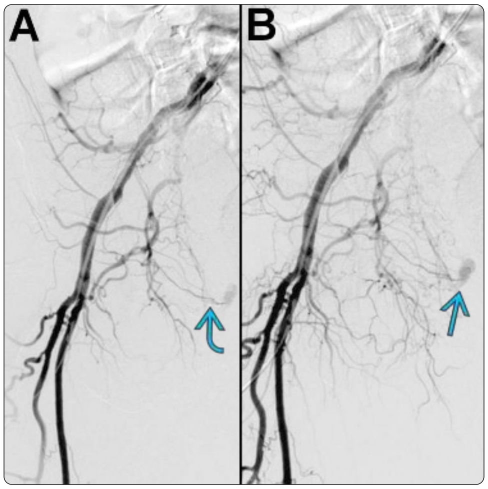
Hemodynamically Unstable Fracture: Diagnostic Pelvic DSA Arteriogram



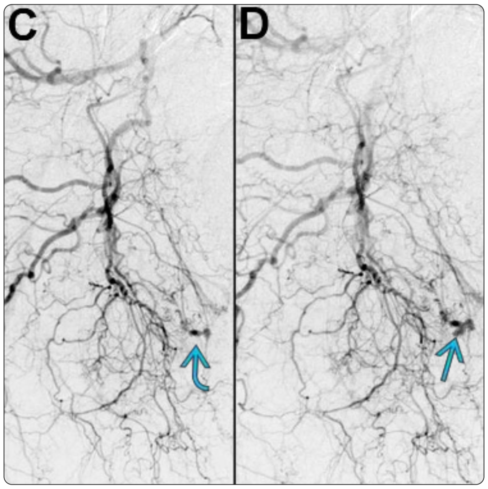
Hemodynamically Unstable Fracture: Diagnostic Pelvic DSA Arteriogram



Hemodynamically Unstable Fracture: Right Common Iliac Artery DSA

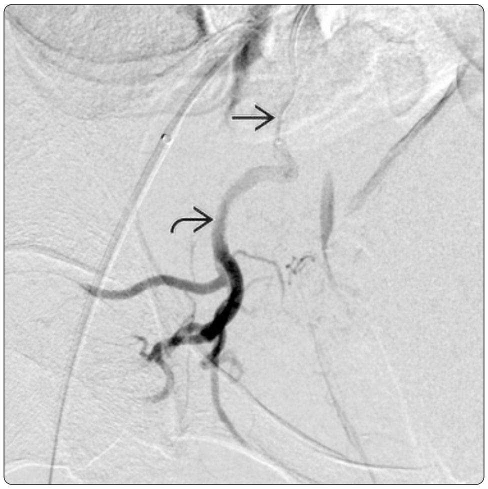


Hemodynamically Unstable Fracture: Right Internal Iliac Artery DSA

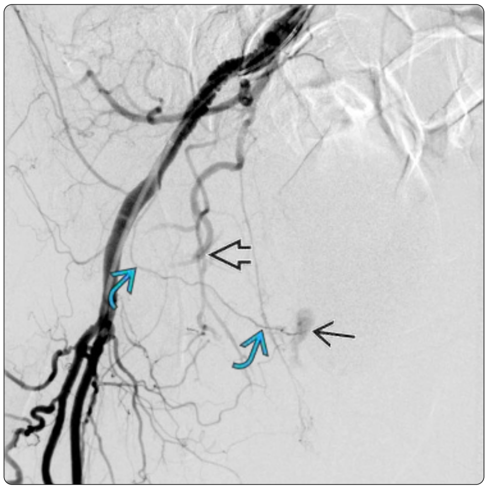


(Left) *(A) DSA shows that the catheter tip has been placed in the distal right common iliac artery near the internal iliac artery origin, using a Waltman loop configuration, and again shows the contrast collection ↪. (B) Slightly later in the DSA sequence, the collection ↪ becomes somewhat more dense but does not change in configuration.* **(Right)** *(C) DSA after placing the catheter in the internal iliac artery shows a contrast collection ↪ that has a somewhat different configuration than on previous imaging and (D) that slightly increases in size ↪ over time.*

Hemodynamically Unstable Fracture: Postembolization Internal Iliac DSA

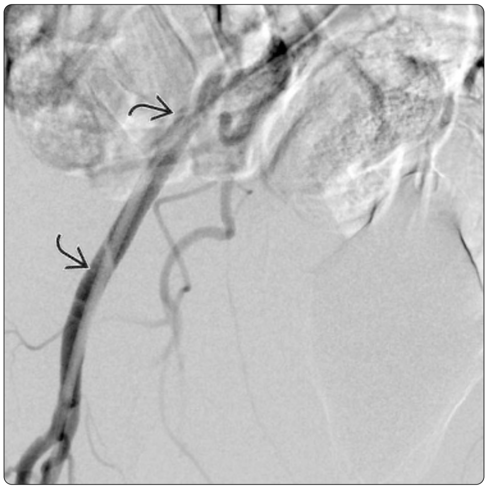


Hemodynamically Unstable Fracture: Postembolization Common Iliac DSA

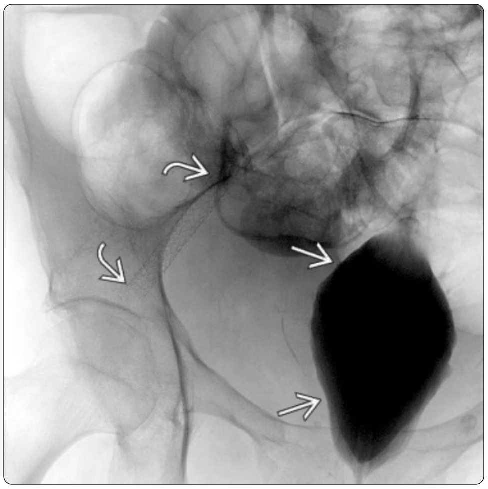


(Left) *Via a microcatheter →, the anterior division ↪ of the internal iliac artery was embolized using a Gelfoam slurry. Afterward, the arteries have a pruned tree appearance, & the distal branches do not fill.* **(Right)** *The catheter was repositioned in the distal common iliac artery. DSA shows that the anterior division branches of the right internal iliac artery no longer fill beyond the main trunk ⇨. The initially seen contrast collection → still remains, however, & is supplied by a small external iliac artery branch ↪.*

Hemodynamically Unstable Fracture: External Iliac Artery Covered Stent



Hemodynamically Unstable Fracture: External Iliac Artery Covered Stent



(Left) *Attempts to catheterize the feeding branch from the external iliac artery were unsuccessful. A balloon-mounted covered stent ↪ was introduced via right transfemoral access & was placed in the distal external iliac artery, covering the origin of the feeding artery.* **(Right)** *The patient's blood pressure stabilized after Gelfoam embolization and covered stent placement. Fluoroscopic image obtained after removal of the femoral access sheath shows the position of the covered stent ↪ and the displaced bladder →.*

Uterine Artery Embolization

KEY FACTS

TERMINOLOGY

- **Uterine leiomyoma (fibroid)**: Benign uterine tumor; originates from myometrium & connective tissue
- **Uterine artery embolization**: Transcatheter particle delivery to block uterine artery blood supply
    - Primarily used for treatment of uterine fibroids
    - Also used to treat **postpartum hemorrhage (PPH) and adenomyosis**

PREPROCEDURE

- MR with gadolinium: Preferred imaging modality
    - Fibroids: T2 hypointensity relative to myometrium, arterial enhancement of fibroids
    - Adenomyosis: Junctional zone > 12 mm; punctate low/high signal intensity areas in myometrium

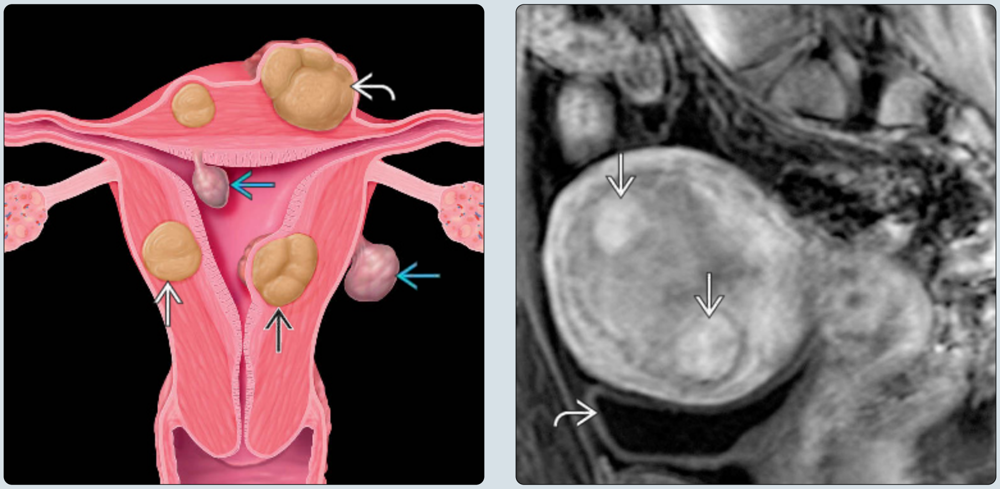
PROCEDURE

- Catheterize contralateral internal iliac artery
- Coaxially place microcatheter via selective catheter
    - Catheterize uterine artery, obtain DSA
- Perform embolization via microcatheter
    - Tris-acryl gelatin (Embospheres): 500-700 μm
- Embolize to near stasis
- Repeat for ipsilateral uterine artery

OUTCOMES

- Fibroids
    - Technical success: 84-100%; most series > 95%
    - Menorrhagia control (81-96%), pelvic pain (70-100%), bulk symptoms (46-100%)
    - Patient satisfaction: 80-90%
    - Symptomatic recurrence: 15% at 3 years
- Adenomyosis: Overall symptomatic improvement
    - Short term: 83-93%
    - Long term: 65-82%
- PPH: control (71-90%)

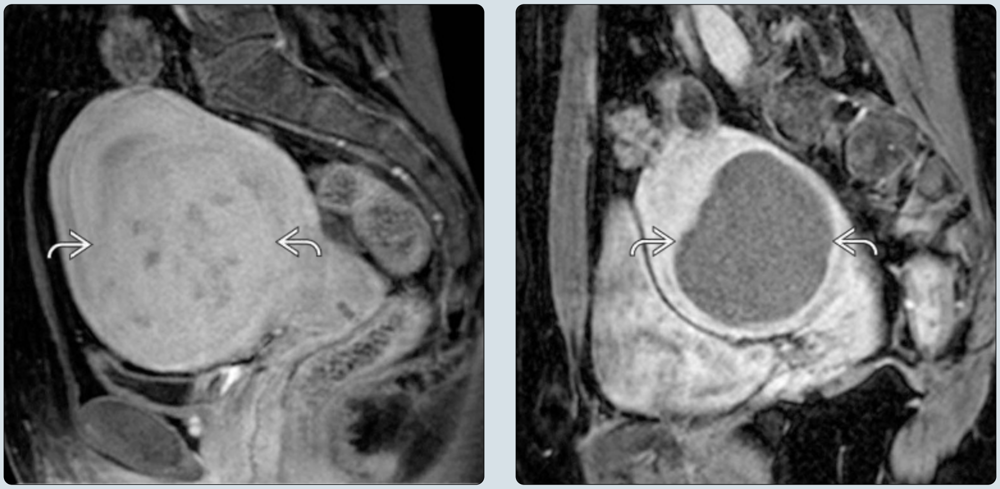
(Left) *A coronal graphic of the uterus shows intramural* ➡*, submucosal* ⇨*, & subserosal* ↪ *fibroids, which may all be treated with uterine artery embolization (UAE). When the latter 2 types are pedunculated* ⇨*, there is a risk of fibroid detachment into the peritoneal or uterine cavity.* **(Right)** *A sagittal gadolinium-enhanced T1WI in a patient with pelvic pain & urinary frequency shows 2 enhancing intramural uterine fibroids* ➡*. The enlarged uterus compresses the urinary bladder* ↪*.*



Anatomic Classification of Fibroids

MR Appearance of Fibroids

(Left) *A sagittal gadolinium-enhanced T1WI FS MR of the uterus in a patient with pelvic pain shows a large intramural fibroid* ↪ *with avid contrast enhancement. The enlarged uterus is compressing adjacent pelvic structures.* **(Right)** *A sagittal T1WI C+ FS MR of the uterus 6 months after bilateral UAE shows nonenhancement of the fibroid* ↪ *& a reduction in diameter, indicating successful devascularization & less compression on adjacent pelvic structures.*



Pre-UAE

Post-UAE

TERMINOLOGY

Synonyms

- Uterine fibroid embolization

Definitions

- **Uterine leiomyoma (fibroid)**: Benign uterine tumor originating from smooth muscle (myometrium) & accompanying connective tissue
- **Uterine artery (UA) embolization (UAE)**: Transcatheter particle delivery to block UA blood supply
  - Primarily used for treatment of uterine fibroids
  - Also used to treat **postpartum hemorrhage (PPH)**
- **PPH**: Excessive bleeding during/after childbirth; may be life-threatening
  - Characterized by
    - Blood loss > 500 mL during vaginal delivery
    - Blood loss > 1,000 mL during cesarean section
    - Hematocrit drop ≥ 10% between admission & birth
  - Causes of PPH
    - Uterine atony
      - Most common cause; up to 80% of cases
    - Genital tract laceration
      - 2nd most common cause
    - Retained/adherent placenta
      - Prevents adequate uterine contraction
    - Maternal coagulopathies
  - Primary PPH: Occurs in first 24 hours after delivery
    - Associated with uterine atony or laceration
  - Secondary (delayed) PPH: Continued bleeding > 24 hours after delivery
    - Associated with retained gestational products
- **Adenomyosis**: Ectopic endometrial tissue in myometrium; can cause painful &/or profuse menses

Pertinent Vascular Anatomy

- Internal iliac artery originates from bifurcation of common iliac artery; has 2 divisions
  - Anterior division
    - Obturator artery
    - Superior vesical artery
    - Vaginal (female patients)/inferior vesical (male patients) artery
    - Middle rectal artery
    - Internal pudendal artery
    - Inferior gluteal artery
    - UA
      - Vaginal artery may arise from UA
  - Posterior division
    - Superior gluteal artery
    - Lateral sacral artery
    - Iliolumbar artery
- Ovarian artery (OA)
  - Arises from abdominal aorta below renal arteries
    - Courses in ovarian suspensory ligament

PREPROCEDURE

Indications

- Symptomatic leiomyomas (fibroids)
  - Established nonsurgical treatment option for leiomyoma management
    - Requires careful patient selection
  - Symptoms
    - Severe menstrual cramps
    - Menorrhagia, metrorrhagia; may cause anemia
    - Bulk/pressure symptoms
      - Pelvic heaviness, bloating, discomfort
      - Urinary frequency, urgency, nocturia
    - Reduced fertility
    - Pelvic pain/dyspareunia related to fibroid
- **Adenomyosis**: Treatment for nonsurgical candidate
- **PPH**
  - Factors predicting need for UAE to control PPH
    - Abnormalities of placentation
    - Abnormal fibrinogen/international normalized ration (INR)/troponin
- Preoperative: Embolization prior to surgical resection of uterine tumors to reduce intraoperative blood loss
- Postoperative: Persistent vaginal bleeding after gynecologic surgery
  - Bleeding may continue after surgical PPH treatment
    - Associated with extrauterine arterial source
- Abnormal placentation
  - Placenta accreta associated with life-threatening intrapartum hemorrhage/PPH
    - Catheter-based prevention/treatment options
      - Place intraarterial balloon catheters in internal iliac artery anterior divisions before delivery
      - Embolize post delivery while placenta in place
  - Transcatheter methods still somewhat controversial

Contraindications

- **Absolute**
  - Viable pregnancy
  - Chronic endometritis
  - Active infection
  - Malignancy in setting of fibroids/adenomyosis
    - Leiomyosarcoma/endometrial/cervical cancer
- **Relative**
  - Coagulopathy
  - Renal insufficiency; iodinated contrast allergy
  - Desire for future pregnancy
    - Cannot guarantee fertility after UAE
    - Very low-level evidence suggests better fertility associated with myomectomy vs. UAE
  - Pedunculated subserosal fibroids
    - Anecdotal safety concerns not supported by larger investigations revealing similar safety outcomes as patients without pedunculated fibroids

Preprocedure Imaging

- MR with gadolinium
  - Preferred modality for pre-UAE fibroid evaluation
    - MR characteristics of fibroids
      - T2 hypointensity relative to myometrium, arterial enhancement post gadolinium
      - T1 hyperintensity without arterial enhancement: Hemorrhagic degeneration
    - Position of fibroids: Pedunculated vs. sessile, submucosal vs. subserosal

      - If stalk of pedunculated fibroid involves > 1/3 of fibroid diameter, consider laparoscopic resection
    - Fibroid size; compression of adjacent structures
      - Predictive of postprocedural clinical outcome
      - Uterus size > 24 weeks gestation may be technically challenging to embolize
  - Adenomyosis: Junctional zone > 12 mm
    - Ill–defined low signal intensity myometrial foci
    - Punctuate high signal intensity myometrial foci
    - Sensitivity up to 88%; specificity up to 93%
- Other imaging: US/CT
  - CT if claustrophobic patient/MR contraindication
  - Doppler US examination of uterine cavity
    - Obstetric & gynecologic emergencies

Getting Started

- Things to check
  - Clinical history & physical examination
  - Clinical work-up
    - Endometrial biopsy
      - Age > 45 years; abnormal vaginal bleeding
    - Pap smear
    - Full gynecologic work-up
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Normal creatinine & eGFR > 60
    - CBC
      - Platelet count > 50,000/μL
    - Coagulation profile
      - INR ≤ 1.5
      - Normal PT, partial PTT
    - β human chorionic gonadotropin
      - Pregnancy exclusion (day of procedure)
  - Written informed procedural consent
  - Review preprocedural imaging
- Medications
  - Antibiotics: Prophylaxis recommended, no consensus on 1st choice
    - 1 g of cefazolin (Ancef); 2 g of ampicillin
    - If history of hydrosalpinx, 100 mg of doxycycline twice daily for 7 days
  - Ketorolac tromethamine (Toradol) 30 mg IV
    - Nonsteroidal antiinflammatory drug
    - Intraprocedural pain control; administer just before UAE
- Equipment list
  - Catheters
    - Nonselective pelvic aortography
      - Flush catheter (e.g., pigtail, OmniFlush)
    - Internal iliac (hypogastric) artery
      - Preformed curved: 5-Fr Roberts, pudendal
      - Cobra catheter
    - OA
      - e.g., 5-Fr Mikaelsson, Simmons, Cobra
    - UA
      - 4- to 5-Fr Cobra-1
  - Microcatheters
    - Renegade Hi-Flo (Boston Scientific; Natick, MA)
      - Preferred with calibrated particles; avoids catheter occlusion
    - Progreat 2.4-2.8 Fr (Terumo Interventional; Somerset, NJ)
    - Maestro (Merit Medical; South Jordan, UT)
      - Curved-tip catheter for tortuous UA
  - Embolic materials
    - Tris-acryl gelatin [Embospheres (BioSphere Medical; Rockland, MA)]: 500-700 μm
      - Preferred embolic agent for fibroids
      - Higher clinical success/lower tumor enlargement incidence
      - No significant differences in inflammatory response compared with polyvinyl alcohol (PVA)
    - Gelfoam pledgets/slurry
    - Nonspherical PVA particles: 300-500 μm (fibroids) & 150-500 μm (adenomyosis)
      - Small particles more effective for adenomyosis
    - Spherical PVA (Contour SE; Boston Scientific; Natick, MA): 700-900 μm
      - Poorer success rate in randomized trial
    - Coils: Microcoils, vascular plugs (pseudoaneurysms only)
  - Guidewires
    - 3-J starter guidewire for access
    - Hydrophilic 0.035" angled guidewire
    - Microwire for use with microcatheter

PROCEDURE

Patient Position/Location

- Unilateral or bilateral common femoral artery access

Procedure Steps

- Place Foley catheter prior to procedure
  - Contrast medium in bladder will potentially obscure fluoroscopic visualization during procedure
- Obtain common femoral artery access
  - Place 5- to 6-Fr access sheath
- Obtain aortogram placing flush catheter at renal/infrarenal level
  - Assess for OA hypertrophy
- Obtain pelvic arteriogram, withdrawing catheter to aortic bifurcation
  - Many operators omit aortic & pelvic DSA; begin with selective internal iliac artery DSA
    - Decreases radiation exposure & contrast volume
- Exchange flush for selective catheter (e.g., Cobra, Roberts catheter)
- Catheterize contralateral internal iliac artery
  - Obtain DSA in contralateral anterior oblique view
    - Facilitates selective catheterization of internal iliac artery anterior division
    - Determines origin of UA
- Place selective catheter in anterior division
- Coaxially place microcatheter via selective catheter
  - Use microcatheter to catheterize UA
    - May use roadmap fluoroscopic guidance
  - Selective catheter may be withdrawn slightly so as not to impede antegrade flow UA
- Place microcatheter tip in horizontal segment of UA

  - Tip should be beyond cervicovaginal branches
- Obtain DSA images via microcatheter
  - Confirm catheter tip beyond branches to ovaries, bladder, or vagina
- Perform embolization
  - Administer 30 mg of IV Toradol
  - Mix embolic agent with dilute contrast
  - Administer embolic agent very slowly
    - Continuously monitor fluoroscopically
    - Avoid reflux of particles
  - **Fibroids**: Mix 10 mL of contrast per particle vial
    - Embospheres/Beadblock: 500-700 μm
    - PVA: 300-500 μm
  - **1-2-3 adenomyosis protocol**: Mix 1 vial nonspherical PVA with 60 mL of 1:1 saline solution/contrast agent mixture for each particle size
    - Embolization protocol: 20 mL 150-250 μm, 40-60 mL 250-355 μm, & complete with 355-500 μm
  - **PPH**
    - Selectivity of catheterization depends on urgency of embolization
      - Can perform embolization from anterior division/main trunk of internal iliac artery if unstable patient
  - **Posthysterectomy/gynecologic surgery bleeding**
    - If no obvious bleeding source, empirically embolize with absorbable gelatin sponge
    - Coil embolization for active focal bleeding source
- Remove microcatheter, flush on back table
- Engage ipsilateral UA
  - Use specially designed/tight-curve catheter to engage ipsilateral internal iliac artery or
  - Form Waltman loop with selective catheter
    - Position catheter tip contralateral to external iliac artery
    - Advance guidewire through catheter to superior apex of curve (aortic bifurcation)
    - Advance wire & catheter together while spinning catheter counterclockwise
    - Catheter will advance into aorta, not down iliac artery
    - Advance wire just outside of catheter
    - Pull catheter & wire down into ipsilateral internal iliac artery
    - Confirm catheter location with contrast
    - At end of procedure, readvance catheter & wire into aorta prior to removal
      - Carefully observe catheter as it is removed
  - Advance microcatheter into ipsilateral UA, perform DSA, deliver embolic
- Embolization endpoint
  - **Fibroids**
    - Controversial: Several protocols described depending on embolic agent
      - "Embo-light": Limited embolization
      - Complete UA occlusion
    - PVA particles: Embolize to stasis; stop if
      - Contrast stasis in UA for 5-10 heart beats
      - Reflux of contrast toward UA origin/into internal iliac artery
    - Embospheres: Pruned-tree appearance
      - Main UA patency; perifibroid plexus occlusion
      - Sluggish forward flow in UA
  - **Adenomyosis**
    - Complete blood flow cessation in ascending UA for 10 cardiac beats
  - **PPH, pre-/postoperative embolization**: Arterial stasis
- Final flush aortography: Performed with flush catheter at infrarenal/aortic bifurcation level
  - Devascularization of fibroids
  - OA collateral supply
    - May address with additional procedure
    - Minimal increase in risk of premature menopause
    - Discuss with patient before embolization
    - Embolize to stasis with particles
- **Superior Hypogastric Nerve Block (SHNB):** Optional technique to deliver local anesthetic; can decrease postembolic-related pain & increase patient satisfaction
  - Position catheter across aortic bifurcation from access site to contralateral iliac artery
    - Splays & allows localization of aortoiliac arteries
  - Sterilely prep periumbilical skin
  - Administer local lidocaine to skin & peritoneal surface overlying L5
  - Advance 21- to 22-gauge needle posterior (5-15° craniocaudal tilt ideal) until contacting vertebral body
    - Needle may pass through bowel without adverse outcome
    - Do not advance into L4/L5 disc space
  - Inject contrast, confirm extravascular spread with AP & lateral imaging
  - Then inject 15-20 mL 0.5% of bupivacaine
    - Maintain slight forward pressure on needle/bone contact during injection
    - If not evenly, medially distributed, consider repositioning needle

Findings and Reporting

- Description of relevant arterial anatomy
  - Arterial supply to fibroids
    - Bilateral UA supply most common
    - OA supply
      - Occurs in 5-10% of patients
    - OA-UA anastomosis classification (Razavi classification)
      - Type I anastomosis: Flow from OA to uterus via anastomosis from main UA
      - Type II anastomosis: OA supplies fibroids directly; recommend OA embolization
      - Type III anastomosis: Major ovarian blood supply directly from UA
    - Genitopudendal trunk: Common
    - Inferior mesenteric artery: Very rare
  - PPH findings
    - Extravasation vs. no active bleeding source
      - UAE can stop bleeding even if no extravasation
    - Enlarged UAs supplying gravid uterus
      - OA contribution may be seen
  - Embolization before/after gynecologic surgery
    - Potential for extensive collaterals, particularly with malignancy
      - Can cause persistent pelvic bleeding

Alternative Procedures/Therapies

- Radiologic
  - MR-guided focused US
  - Radiofrequency ablation
- Surgical
  - Hysterectomy
  - Myomectomy (open or laparoscopic)
  - Laparoscopic bilateral ligation of UAs
- Other
  - Endometrial ablation
  - Gonadotropin-releasing hormone agonist

POST PROCEDURE

Things to Do

- Overnight admission for observation & hydration
- Address postembolization syndrome (very common)
  - Pelvic pain, nausea/vomiting/appetite loss begins 2-3 hours post procedure, plateau at 8-12 hours
  - Low-grade fever & malaise peak 2-3 days post procedure
  - Medications
    - Morphine/hydromorphone via patient-controlled analgesia (PCA) pump
    - 30 mg of IV Toradol every 6 hours (3 doses)
    - Zofran or Compazine IV for nausea
  - If SHNB performed, anesthetic effect typically lasts 8-12 hours
- Postprocedure day 1
  - D/C Foley, PCA, IV medications
  - Encourage PO intake
  - Expect discharge from hospital
- Discharge from hospital
  - Oral pain medication
    - 600 mg of Ibuprofen every 6 hours x 5-7 days
    - Percocet or Vicodin can be prescribed
  - Usual return to normal activity 4 days-1 week
  - Decrease physical activity 3-5 days
  - Avoid tampons & intercourse x 1 week
  - Expect vaginal discharge x 1-2 weeks

Things to Avoid

- Nontarget embolization
- Overembolization

Clinical Follow-Up

- 2 weeks & 3 months post procedure
- 6-month clinic visit with MR

Postprocedure Imaging

- MR
  - Fibroids
    - Devascularized fibroids/preserved myometrial enhancement
  - Adenomyosis
    - Uterine volume & junctional zone reductions up to 54.0% & 23.9%, respectively
    - Dark signal intensity most favorable MR predictive factor for UAE effectiveness

OUTCOMES

Complications

- Most feared complication(s)
  - Nontarget embolization: < 1%
  - Uterine necrosis with sepsis
  - Misdiagnosed uterine malignancy
    - American Congress of Obstetricians & Gynecologists estimate 1:500 occurrence (after myomectomy/hysterectomy), varies with age
- Immediate/periprocedural complication(s)
  - Access site complications
  - Arterial dissection/occlusion
  - Contrast-induced nephropathy
- Delayed complication(s)
  - Fibroid expulsion; detachment into peritoneum: 3-15%
  - Infection/septicemia: 1-3%
  - Myometrial ischemia
  - Persistent vaginal bleeding
  - Prolonged vaginal discharge: 2-17%
  - Permanent amenorrhea; ovarian failure
    - Age > 45: 20-40%
    - Age < 45: 0-3%

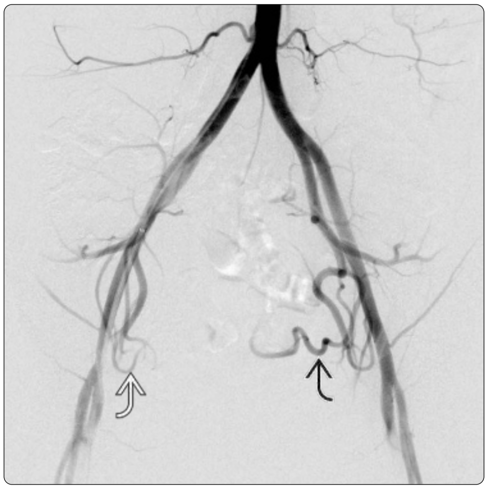
Expected Outcomes

- **Fibroids**
  - Technical success: Defined as successful embolization of both UAs
    - Reported rates: 84-100%; most series > 95%
  - Rate of clinical success/symptomatic improvement
    - Menorrhagia control: 81-96%
    - Pelvic pain: 70-100%
    - Bulk-related symptoms: 46-100%
    - Fibroid size reduction: 50-60%
    - Elimination of symptoms: 75%
  - Patient satisfaction: 80-90%
  - Recurrence of fibroid-related symptoms
    - 15% at 3 years: Up to 17% at 6 years
  - UAE vs. myomectomy or hysterectomy
    - Patient preference: Inconclusive 2 & 5 years after procedures
    - Reintervention rate: UAE > surgery
    - Major complications: No difference
    - Minor complications: UAE higher, but risk of blood transfusion lower
- **Adenomyosis**
  - 1-2-3 protocol: 82.5% complete necrosis by MR
  - Overall symptomatic improvement
    - Short term: 83-93%; long term: 65-82%
  - May need additional treatment for recurrent symptoms in up to 50% of patients
- **PPH**
  - Technical success: 71-90%
  - Repeat procedure rates: Up to 18%
  - Need for total abdominal hysterectomy: Up to 17%

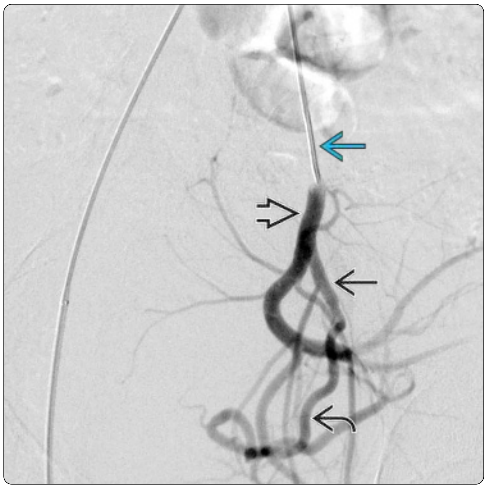
SELECTED REFERENCES

1. Dariushnia SR et al: Quality improvement guidelines for uterine artery embolization for symptomatic leiomyomata. J Vasc Interv Radiol. 25(11):1737-47, 2014

Step-by-Step: UAE (Initial Pelvic DSA)

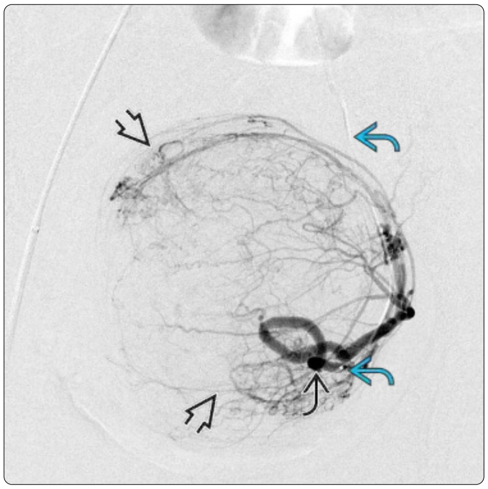


Step-by-Step: UAE (Left Internal Iliac DSA, RAO Projection)

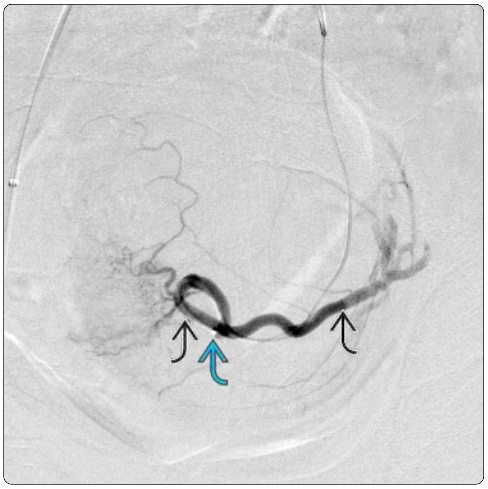


(Left) *A pelvic DSA performed from a right femoral arterial access shows a small right ↪ & an enlarged left uterine ↪ artery. Many operators omit the pelvic arteriogram & proceed directly to selective internal iliac DSA, thereby decreasing radiation & contrast. Others add an infrarenal aortogram to assess for ovarian artery hypertrophy.* **(Right)** *A Cobra catheter → has been advanced over the aortic bifurcation into the left internal iliac artery ⇨. The uterine artery ↪ arises from the anterior division →.*

Step-by-Step: UAE (Left Uterine DSA)

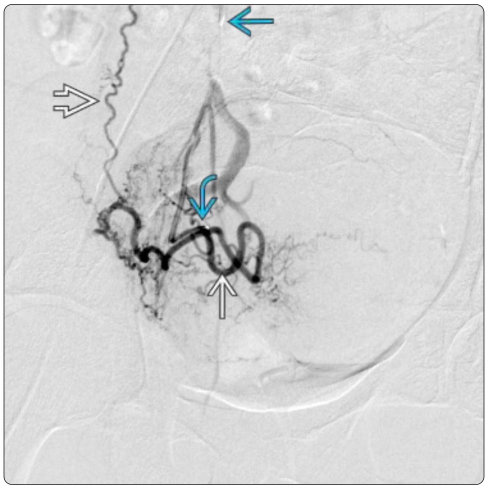


Step-by-Step: UAE (Postembolization, Left Uterine DSA)

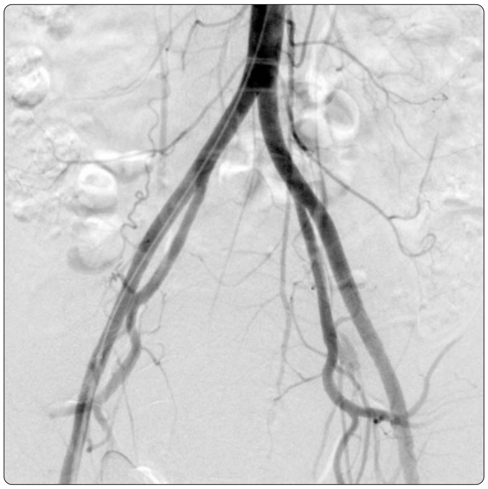


(Left) *The Cobra catheter is advanced into the anterior division of the internal iliac artery. A microcatheter ↪ is then coaxially introduced into the uterine artery ↪. DSA shows an extensive arterial supply outlining the large fibroid ⇨.* **(Right)** *The microcatheter tip ↪ is advanced more distally into the horizontal portion of the uterine artery ↪. Embospheres (500-700 μm) mixed with contrast are slowly delivered. The embolization endpoint is sluggish forward flow in the uterine artery, termed near stasis.*

Step-by-Step: UAE (Right Uterine Artery DSA)



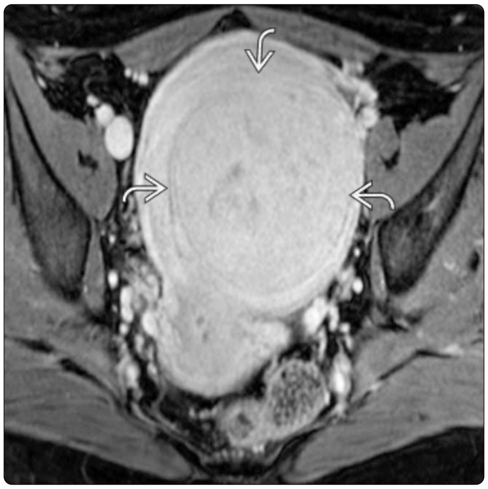
Step-by-Step: UAE (Postembolization Pelvic DSA)



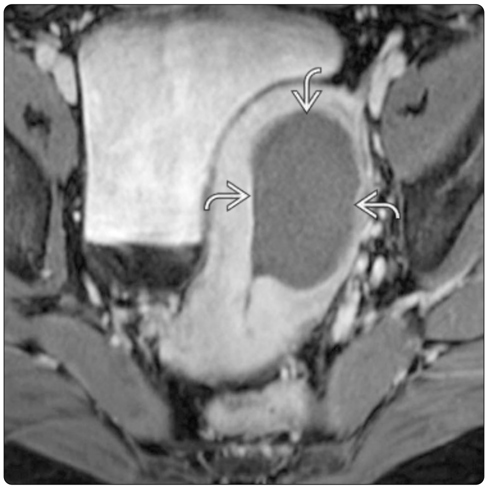
(Left) *After the left UAE, a Waltman loop is formed with the Cobra catheter, & the tip → is withdrawn into the anterior division of the ipsilateral internal iliac artery. The right uterine artery → is catheterized with a coaxial microcatheter ↪, & embolization is performed. Retrograde filling of a type I ovarian-to-uterine artery anastomosis (with flow from the ovarian artery ⇨ to the uterus) is noted.* **(Right)** *A final pelvic DSA shows no filling of the uterine arteries & no fibroid opacification.*

(Left) *It is important to document the appearance of the uterus both before & after UAE using the same imaging modality for comparison purposes. Prior to UAE, the large intramural fibroid ➦ avidly enhances with contrast.* **(Right)** *The patient is typically seen in a follow-up clinic visit at 2 weeks & 3 months after the UAE. An additional clinic visit should take place ~ 6 months after UAE, at which time this post-UAE axial T1WI C+ MR demonstrates complete fibroid devascularization ➦.*

Documentation of Results: Pre UAE

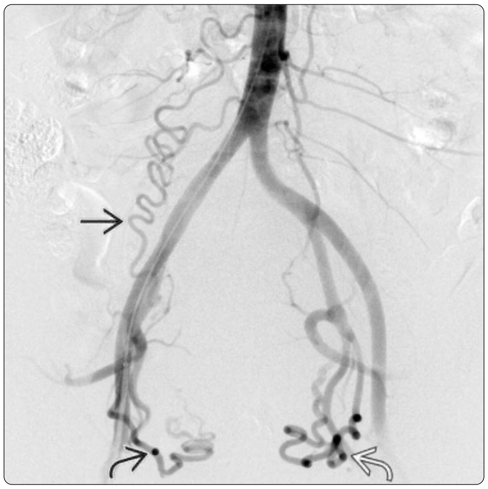


Documentation of Results: Post UAE

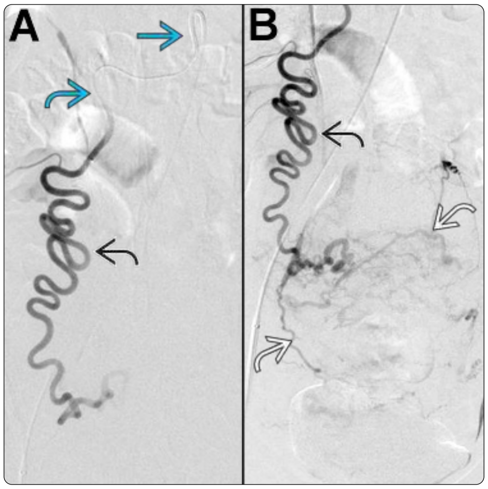


(Left) *A DSA abdominal aortogram obtained during a UAE procedure in a patient with symptomatic fibroids shows enlarged right ↪ & left ➦ uterine arteries & a very prominent right ovarian artery →.* **(Right)** *A DSA shows (A) selective catheterization of the right ovarian artery with a reverse-curve catheter → & a coaxial microcatheter ↪. (B) The ovarian artery ↪ provides a direct blood supply to the fibroid ➦, classified as a type II anastomosis. This can be a cause of UAE treatment failure if only the uterine artery is embolized.*

Ovarian-to-Uterine Artery Anastomosis: Razavi Type II Anastomosis

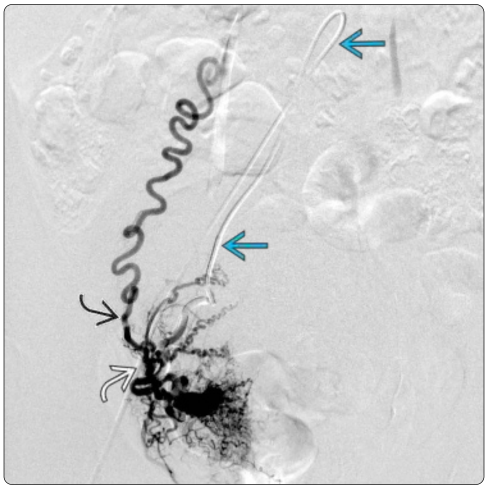


Ovarian-to-Uterine Artery Anastomosis: Razavi Type II Anastomosis

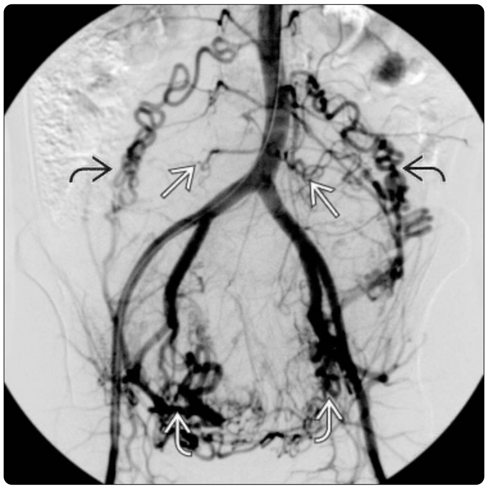


(Left) *A DSA shows right uterine artery catheterization with a Waltman loop → & a microcatheter. The ovarian ↪ artery has an anastomosis with the intramural portion of the uterine artery ➦. Although the ovarian artery provides vascularity to the fibroid, UAE devascularizes the tumor & blocks flow distal to the anastomosis.* **(Right)** *DSA shows a large fibroid with the arterial supply from the uterine ➦, both ovarian ↪, & the lower lumbar ➡ arteries. Further imaging also showed supply from the inferior mesenteric artery.*

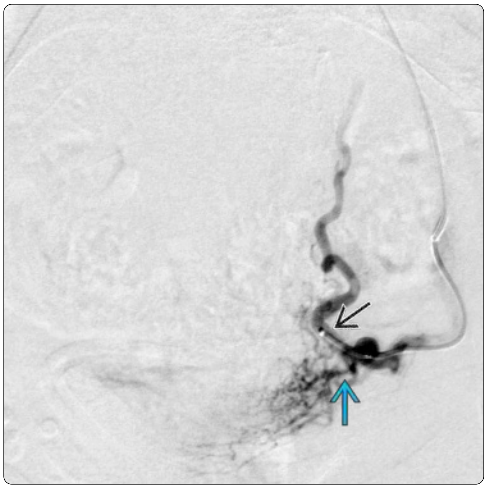
Ovarian-to-Uterine Artery Anastomosis: Razavi Type I Anastomosis



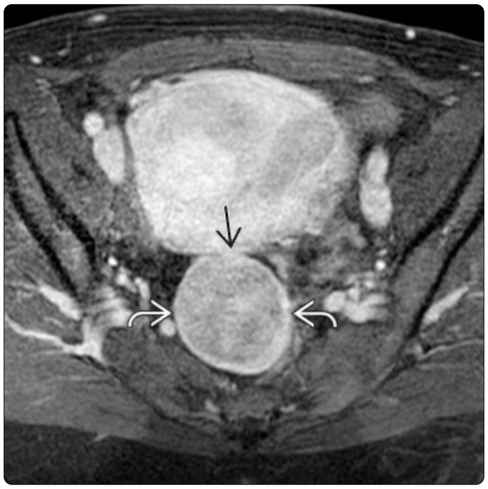
Arterial Recruitment to Fibroid



Cervicovaginal Branch

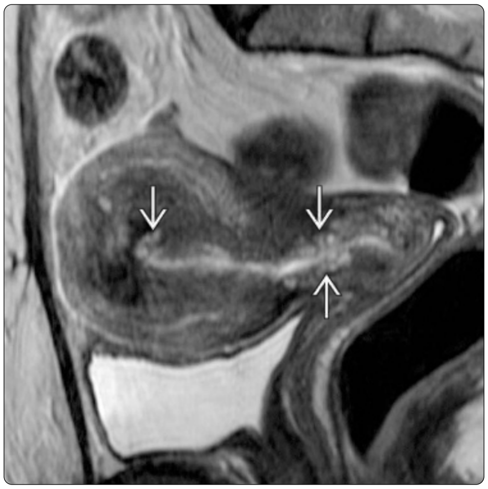


Pedunculated Narrow-Stalk Fibroid

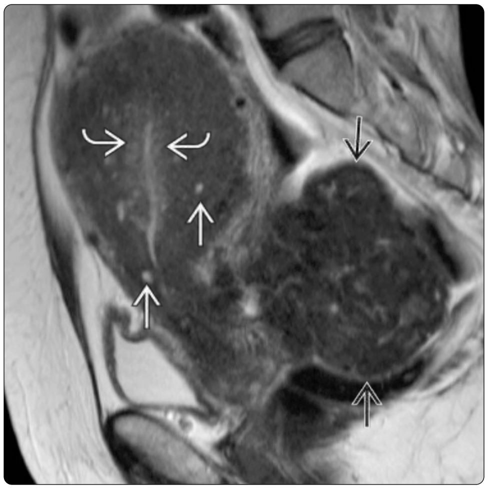


(Left) *This uterine artery DSA shows a microcatheter ⇨ positioned just distal to the cervicovaginal branch ⇨ in preparation for UAE. If the tip were more proximal, or if nontarget reflux embolization to this branch occurs, tissue necrosis could result.* **(Right)** *An axial postgadolinium T2WI FS MR shows a pedunculated posterior fibroid ➡ with a narrow stalk ⇨. There is a risk of fibroid detachment into the peritoneal cavity if this patient were to undergo UAE.*

Uterine Adenomyosis

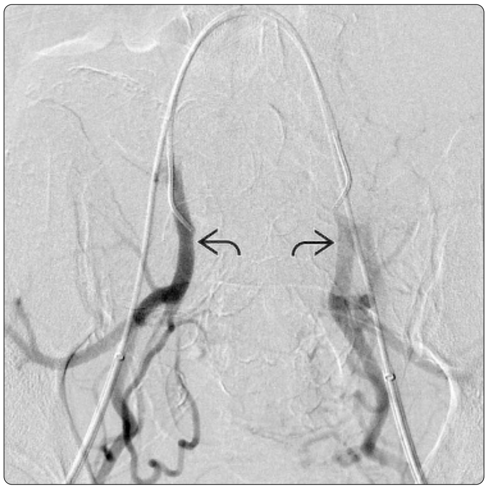


Uterine Fibroid & Adenomyosis

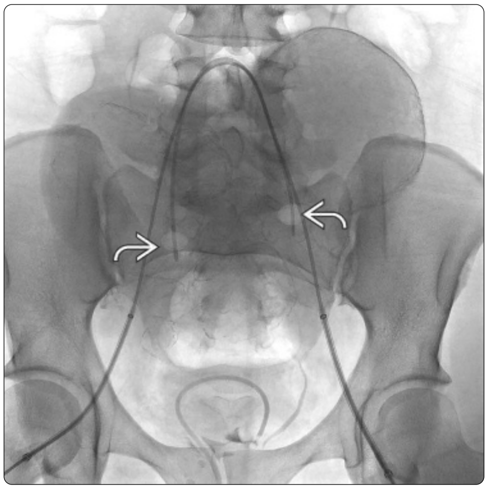


(Left) *Sagittal T2WI MR shows increased junctional zone signal ➡ that is typical of adenomyosis. By using smaller particles during UAE for this indication, investigators report complete necrosis by MR in > 80% & improved symptoms in 50-70% of patients.* **(Right)** *Sagittal T2WI MR shows a subserosal fibroid ⇨ arising posteriorly from the uterus. There is also punctate increased signal ➡ & thickening ➡ of the junctional zone due to adenomyosis, which is ectopic endometrial tissue in the myometrium.*

Hypogastric Artery Occlusion Balloons: Perioperative Hemorrhage Control



Hypogastric Artery Occlusion Balloons: Perioperative Hemorrhage Control



(Left) *Balloon occlusion catheters can be inflated in the internal iliac (hypogastric) arteries for control of uterine artery bleeding. The balloons are positioned preoperatively if excessive bleeding during gynecologic surgery is anticipated & then inflated during the operation as needed. The image shows catheters engaging both hypogastric arteries ⇨.* **(Right)** *The selective catheters have been replaced with balloon occlusion catheters that are inflated ➡ if needed. Hypogastric embolization or UAE are alternative options.*

KEY FACTS

TERMINOLOGY

- **Peripheral artery disease (PAD)**: Obstruction of noncoronary, noncerebral arteries
- **Intermittent claudication (IC)**: Reproducible muscular leg pain after walking, relieved with rest caused by PAD
- **Critical limb ischemia (CLI)**: Rest pain or tissue loss caused by advanced arterial obstruction
- **Acute limb ischemia (ALI)**: Sudden interruption of arterial blood flow to extremity
    - Clinical 6 Ps: **P**ain, **p**ulselessness, **p**allor, **p**aresthesias, **p**aralysis, and **p**oikilothermia (i.e., cold)

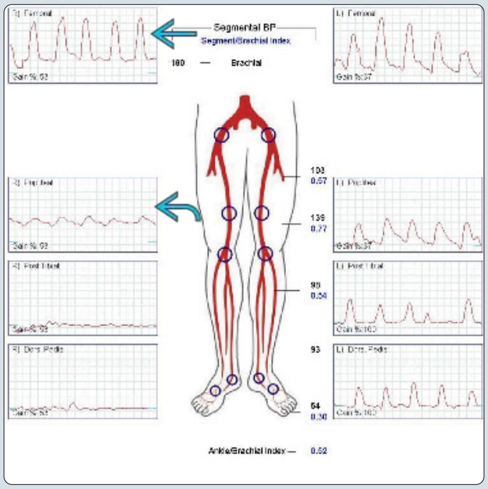
PREPROCEDURE

- Physical exam and physiologic testing with ABI, PVR, and segmental limb pressures are bedrock of preprocedure evaluation; CTA helps with anatomic definition

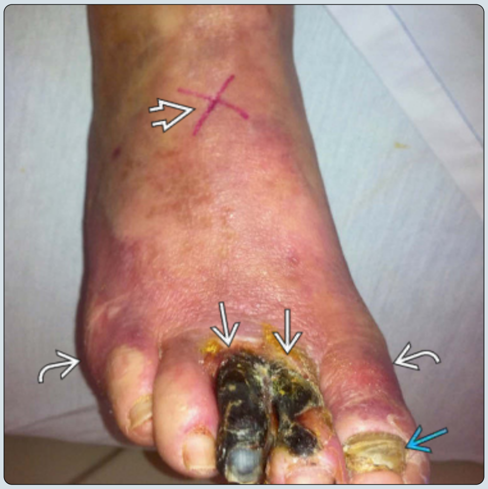
PROCEDURE

- Contralateral retrograde access: SFA, iliac lesions lesions
- Ipsilateral antegrade access: Distal SFA, popliteal, below-knee lesions
- Retrograde tibial access: Useful adjunct when occlusions unable to be crossed from above
- Chronic (IC/CLI) treatment
    - Angioplasty (primary treatment or stenting adjunct)
        - Appropriate for short segment stenoses
        - Poor long-term patency in long stenoses or occlusions
    - Intravascular stent placement
        - Stents typically reserved for long/complex lesions
        - Better outcomes than PTA in these lesions
    - Drug-eluting stents and drug eluting balloons
        - Newer technology with promising results
- ALI treatment (concurrent with systemic anticoagulation)
    - Intrathrombotic injection of concentrated thrombolytic
    - Catheter-directed thrombolysis
    - Mechanical thrombectomy/suction aspiration
    - Stent deployment to displace clot

SFA Revascularization (Initial Noninvasive Testing)

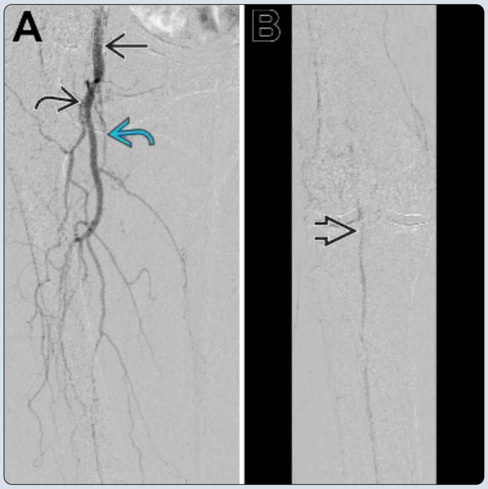


SFA Revascularization (Clinical Photograph)

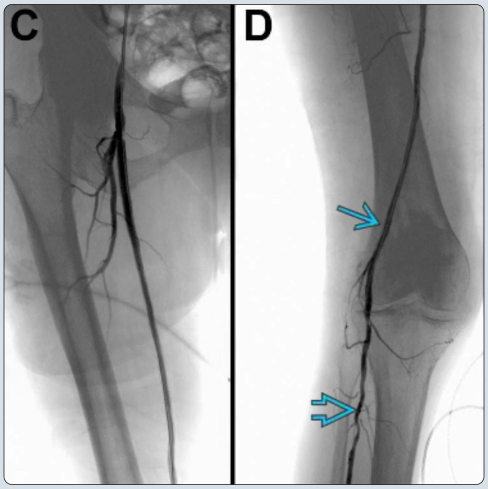


(Left) *A 72-year-old woman with atherosclerotic risk factors including smoking, diabetes, and HTN developed dry gangrene of the 2nd and 3rd rays of her right foot. Noninvasive vascular study shows a marked drop in waveform from the right femoral artery ⇨ to the right popliteal artery ↩ consistent with severe SFA disease.* **(Right)** *Clinical photo shows dry gangrene of the 2nd and 3rd digits ➡, dependent rubor ➡, shiny skin and toenail thickening ⇨, all signs of PVD. A faintly Dopplerable DP pulse was present ➡.*

SFA Revascularization (Initial Angiogram)



SFA Revascularization (Post Recanalization)



(Left) *Initial right lower extremity angiogram demonstrates patent common femoral → and profunda femoris ↪ arteries. A faint channel of the proximal SFA is present ↩. Distally, the runoff (B) shows faint reconstitution of the popliteal artery ⇨.* **(Right)** *Given that she was not a surgical candidate, endovascular recanalization with angioplasty and stenting of this TASC D lesion was performed. In-line flow to the popliteal artery → with preserved single vessel run-off ⇨ was established.*

TERMINOLOGY

Definitions

- **Peripheral artery disease (PAD)** or **peripheral vascular disease (PVD)**
  - Occlusion or stenosis of noncoronary, noncerebral arteries
    - Concurrent atherosclerosis often prevalent elsewhere
    - Symptoms range from asymptomatic to rest pain/tissue loss
  - PAD risk factors same as atherosclerosis elsewhere
    - Age > 50, obesity, male gender, hypertension, hyperlipidemia
    - Diabetes
      - Have more aggressive PAD
      - 5x higher amputation rate
      - Typically affects distal, small-caliber vessels
  - Severity of symptoms depends on degree of stenosis, collateral circulation, intensity of exertion
- **Ankle-brachial index (ABI)**
  - Noninvasive evaluation of peripheral circulation
  - Performed with BP cuff and continuous Doppler
  - Ratio of ankle to brachial systolic pressure
    - Use higher ankle pressure [dorsalis pedis (DP) or posterior tibial (PT)]
    - Divide by higher of 2 brachial artery pressures
  - Interpretation
    - ≥ 1.3: Calcified vessels
      - Medial calcification can be seen in end-stage renal disease or diabetes
      - Unreliable examination as calcification prevents vessel compression
    - 0.9-1.3: Normal
    - < 0.9: Abnormal; indicates presence of PAD
      - 0.4-0.9: Mild to moderate PAD; intermittent claudication (IC) likely
      - < 0.4: Severe PAD; critical limb ischemia (CLI) likely
  - Exercise ankle brachial index
    - Use if resting ABI normal but PAD still suspected
      - More sensitive than resting ABI
    - Abnormal: > 20% ABI decrease with exercise compared to rest
- **Intermittent claudication**
  - Reproducible crampy muscular leg pain with exercise, relieved with rest
    - Pain pattern suggests lesion location
      - Buttock pain: Aorta/common iliac artery
      - Thigh pain: External iliac/common femoral artery
      - Calf pain: Superficial femoral/popliteal artery
      - Foot pain: Tibial/peroneal artery
  - Imbalance of supply and demand of blood flow
  - Treat if lifestyle limiting
  - Typical ABI between 0.4 and 0.9
- **Critical limb ischemia**
  - Rest pain or tissue loss/non-healing wounds
    - Peripheral neuropathy may initially present similarly
      - With CLI, pain worsens when leg elevated, relieved when leg dependent
  - Severe arterial obstruction or occlusion
  - Often multifocal disease
  - Typical ABI < 0.4
- **Acute limb ischemia (ALI)**
  - Sudden interruption of arterial blood flow to extremity
  - Usually due to embolus or in situ thrombosis
    - Embolic source may be cardiac or aneurysm
  - Symptoms: 6 "P"s of acute limb ischemia
    - **P**ain, **p**ulselessness, **p**allor, **p**aresthesias, **p**aralysis, and **p**oikilothermia (i.e., cold)
  - **Society of Vascular Surgery (SVS) classification of acute limb ischemia**
    - I: Viable
      - No sensory loss; no motor loss
      - May have audible Doppler arterial pulse
    - IIa: Marginally threatened
      - Pain/sensory loss, no weakness
    - IIb: Immediately threatened
      - Pain/sensory loss and mild weakness
    - III: Irreversible (nonviable)
      - Anesthesia/paralysis, muscle rigor

Fontaine Stages of PAD

- Stage 1: Asymptomatic but decreased pulses, ABI < 0.9
  - Up to 75% of patients with PAD are asymptomatic
    - Could be related to sedentary/limited lifestyle
- Stage 2: Intermittent claudication
  - 2a: Distance > 200 m
  - 2b: Distance < 200 m
- Stage 3: Ischemic rest pain
- Stage 4: Ulceration, gangrene

Trans-Atlantic Inter-Society Consensus II (TASC II): Categorization of Atherosclerotic Lesions Based on Morphology

- Type A
  - Single stenosis ≤ 10 cm in length
  - Single occlusion ≤ 5 cm in length
  - Endovascular therapy is treatment of choice
- Type B
  - Multiple lesions ≤ 5 cm in length
  - Single stenosis or occlusion ≤ 15 cm in length
  - Heavily calcified lesion ≤ 5 cm in length
  - Typically, endovascular treatment preferred
- Type C
  - Multiple lesions adding up to > 15 cm
  - Recurrent stenosis after 2 endovascular treatments
  - Multiple lesions > 3 but < 5 cm in length
  - Surgery preferred; consider endovascular therapy if high-risk patient for open revascularization
- Type D
  - Chronic total occlusions (CTO) > 20 cm or involving popliteal artery/proximal trifurcation
  - Poor endovascular results, surgery is standard

Infrainguinal Vascular Anatomy

- Common femoral artery (CFA)
  - Continuation of external iliac artery below inguinal ligament
    - Overlies femoral head
    - Angiographic surrogate of inguinal ligament are inferior epigastric/deep circumflex iliac artery origins
  - Bifurcates into superficial and deep femoral arteries

- Superficial femoral artery (SFA)
  - From CFA bifurcation to caudal end of adductor (Hunter's) canal
    - Distal portion of SFA, within adductor canal, is prone to atherosclerotic disease
      - 3/4 of femoropopliteal occlusions occur within adductor canal
      - Proposed etiology of preponderance of atherosclerotic disease: Nonpulsatile deformations at this level
    - Relatively absent of side-branch vessels
- Profunda femoris artery
  - a.k.a. deep femoral artery
  - Extends from femoral bifurcation into thigh musculature
  - Provides important collaterals in setting of SFA stenosis/occlusion
  - Perforating branches resistant to atherosclerosis
- Popliteal artery
  - SFA becomes popliteal artery at adductor hiatus
  - Courses behind knee, between gastrocnemius heads
  - Bifurcates into anterior tibial, tibioperoneal trunk
- Anterior tibial artery (ATA)
  - Passes anteriorly through intraosseous membrane
  - Becomes dorsalis pedis artery at ankle level
- Tibioperoneal trunk
  - a.k.a. tibial fibular trunk
  - Variable but typically short segment
  - Divides into peroneal and posterior tibial arteries
  - Peroneal artery
    - a.k.a. fibular artery
    - Relatively resistant to atherosclerosis
    - Normally patent to just above ankle joint
    - Has communicating branches with ATA
  - PT artery
    - Supplies posterior compartment
      - Distally forms plantar arch of foot

PREPROCEDURE

Indications

- **Claudication**
  - Significant disability or lifestyle limitation
    - No improvement from medical/exercise therapy
- **Critical limb ischemia**
  - Rest pain, ulcers, gangrene
    - Revascularization for limb salvage
- **Acute leg ischemia**
  - SVS I and IIa amenable to endovascular treatment
    - SVS IIb: Immediate revascularization (surgical thrombectomy/bypass)
    - SVS III: Nonviable, proceed to amputation

Contraindications

- Atherosclerotic disease of common femoral artery
  - Surgical endarterectomy treatment of choice
- Advanced/irreversible ulceration/gangrene
  - Nonviable tissue; requires amputation
- Popliteal artery entrapment
  - Repetitive compression of artery may cause arterial stenosis/occlusion
    - No role for endovascular therapy
    - Surgical release of abnormal musculature/tendon ± vascular bypass of diseased segment
- Popliteal artery cystic adventitial disease
  - Surgical resection of diseased segment and bypass
- TASC type D lesion
  - Consider surgical bypass treatment of choice
    - Endovascular intervention sometimes used if patient is poor operative candidate
- Contraindications to thrombolysis
  - Absolute
    - Recent internal bleeding, stroke, neurosurgery, intracranial trauma; known intracranial neoplasm
  - Relative
    - Recent surgery/trauma/severe hypertension
- Uncorrectable coagulopathy

Preprocedure Imaging

- **Noninvasive arterial evaluation**
  - **ABI**
    - Verifies vascular origin of pain
    - Can be followed after intervention
  - **Segmental limb pressures**
    - Cuffs placed at proximal thigh, distal thigh, below knee, above ankle
    - Allows approximate localization of disease
      - BP drop of ≥ 20 mm Hg indicates hemodynamic stenosis between cuffs
  - **Pulse volume recording (PVR)**
    - Displayed as waveforms
    - Uses air plethysmography to measure limb volume/changes in blood flow
      - Normal: Sharp systolic upstroke, dicrotic notch in downstroke
      - Mild/moderate disease: Loss of sharp upstroke, loss of dicrotic notch, prolonged downslope
      - Severe: Blunt/flattened, low-amplitude waveform
  - **Transcutaneous oximetry (TcpO2/TCOM)**
    - Tissue perfusion testing
    - Wound healing likely when TcpO2 > 40 mm Hg
    - Wound healing unlikely when TcpO2 < 20 mm Hg
- **Duplex US**
  - Characterizes lesion morphology/severity/extent
  - Findings in 51-75% stenosis
    - Prestenosis: Normal
    - Intrastenosis: Peak systolic velocity (PSV) elevated > 2x normal
    - Poststenosis: Partial turbulence
  - Findings in 76-99% stenosis
    - Prestenosis: Increased pulsatility
    - Intrastenosis: Increased PSV > 4x normal
    - Poststenosis: Marked turbulence
- **Computed tomography angiography (CTA)**
  - Excellent delineation of arterial anatomy/pathology
    - Characterization of target lesion(s)
  - Similar accuracy to digital subtraction angiography
- **Magnetic resonance angiography (MRA)**
  - Excellent delineation of arterial anatomy/pathology
    - Contrast and noncontrast techniques available

Getting Started

- Things to check
  - Clinical history and physical examination
    - Comprehensive cardiovascular evaluation
      - Detailed pulse examination/Doppler evaluation
    - Review prior endovascular/surgical interventions
      - May influence choice of optimal access
    - Current medications
      - Any anticoagulants/antiplatelet agents
  - Laboratory parameters
    - Prefer eGFR > 45, platelet count > 50,000/μL, international normalized ratio (INR) ≤ 1.8
    - Consensus guidelines suggest INR < 1.5 for arterial intervention with access up to 7 Fr
- Medications
  - Heparin
    - Bolus 2,500-5,000 U; then infusion of 1,000 U/hr
    - **Bivalirudin** (Angiomax) utilized for heparin allergy
  - Clopidogrel (Plavix)
    - Consider loading dose before revascularization
      - 300 mg minimum loading dose
    - Continue maintenance dose post procedure
      - 75 mg daily dose for 4-6 weeks minimum
  - Tissue plasminogen activator (tPA)
    - Often manufactured using recombinant technology
    - Cleaves zymogen plasminogen into plasmin, which then acts to degrade fibrin clots
- Equipment list
  - Access sheaths
    - 5- to 8-Fr vascular access sheath
    - Crossover access sheath (contralateral access), e.g., Flexor Balkin (Cook Medical), Destination (Terumo)
    - 2.9-Fr pedal sheaths (Cook Medical)
  - Diagnostic catheters
    - Flush (e.g., pigtail, OmniFlush) or straight catheter
  - Selective catheters
    - May be used to direct guidewire across lesion
    - Hydrophilic catheter often useful in crossing lesion
  - Support catheters
    - Low profile, torquable, high pushability, e.g., CXI (Cook Medical), Rubicon (Boston Scientific)
  - Thrombolysis infusion catheters
    - Multisidehole infusion catheters (e.g., Uni*Fuse-AngioDynamics or EKOS-BTG)
  - Angioplasty (PTA) balloon catheter
    - Conventional, cutting and drug-eluting balloons
    - Over-the-wire and monorail
    - Insufflator for controlled inflation
  - Guidewires
    - Angled or straight-tipped hydrophilic guidewire
      - Often beneficial for crossing lesion
    - Stiff guidewire (e.g., Amplatz, Rosen)
      - Stability when advancing devices across lesion
      - Exchange length (240 cm) for distal lesions
    - 0.018" wires for certain stent deployments (Viabahn, Gore Medical) and for low-profile balloons
  - Stents
    - Noncovered, self-expanding (multiple options)
      - Preferred in femoropopliteal revascularization
      - Available in long lengths (e.g.,100-120 mm)
    - Covered, self-expanding (multiple options)
      - Reported improved outcomes vs. noncovered
      - Advantages: Flexible, fracture resistant
    - Drug-eluting
  - Atherectomy: Various proprietary device options

PROCEDURE

Patient Position/Location

- Best access approach: Depends on lesion location and patient body habitus
  - Ipsilateral antegrade access
    - For distal SFA, popliteal or below-knee lesions
    - Difficult with obese patients
  - Contralateral retrograde access
    - For SFA lesion or with concurrent iliac disease
  - Retrograde tibial access
    - Typically DP artery, alternative is PT artery
    - Used as adjunct after failed attempt at recanalization from above
  - Retrograde popliteal access

Procedure Steps

- **General**
  - Obtain arterial access, insert access sheath, place diagnostic catheter
  - Perform DSA
    - Identify lesion, collaterals, baseline distal runoff
    - Determine optimal intervention
  - Administer heparin bolus (2,500-5,000 U)
  - Cross lesion
    - Use support catheters, re-entry catheters if needed
    - Consider tibial access if cannot cross from above
- **Chronic PAD (IC/CLI) treatment options**
  - Angioplasty
    - Oversize balloon diameter by 20% compared with adjacent normal segment
      - Perform angioplasty
    - Withdraw PTA balloon, leave guidewire across lesion
      - Perform postangioplasty DSA
    - Primary PTA as sole intervention
      - Appropriate for short segmental stenoses with good post intervention results
    - Precursor to stenting
      - May need PTA prior to stent passage across lesion
      - Long segment lesions or total occlusions: Poor long-term patency with angioplasty alone
    - PTA with drug-coated balloon (DCB)
      - Femoropopliteal: Robust data suggests utilizing DCB vs. standard PTA; data lacking comparing DCB vs. bare metal/drug eluting stents
      - Infrapopliteal: Nonuniform studies; DCB vs. standard PTA ambiguous
  - Intravascular stent placement
    - Use self-expanding stents only
      - Balloon expandable stents prone to crushing with external compression
    - Covered stents (e.g., Viabahn, Gore Medical)
      - Best long-term results in SFA disease
      - May also be used in cases of in-stent restenosis

      - Ensure stent not covering important collaterals
    - Drug-eluting stents (e.g., Zilver PTX, Cook Medical)
      - Possible advantage vs. bare metal stents
    - Certain bare metal stents: Flexible, lack of fracturing and high radial strength, advantageous at sites of flexion or with heavily calcified lesions (e.g., Supera, Abbott Vascular)
    - Diameter: Stent > 20% normal artery diameter
    - Length
      - Stent entire diseased segment extending both ends into normal adjacent arterial segments
      - Prefer single long-length stent when possible
      - If multiple stents needed for long lesions, overlap sequential stents by roughly 1 cm
    - Location: Avoid sites of flexion/access (e.g., CFA, popliteal)
  - Atherectomy
    - May be 1° intervention or adjunct to PTA/stenting
    - May use to "debulk" atheroma from focal lesion
- **ALI treatment options**
  - Systemic anticoagulation: Start heparin immediately upon diagnosis of ALI
  - Intrathrombotic injection of thrombolytic
    - 5-10 mg tPA often injected over 1-2 min
    - Inject via multiple-sidehole catheter, pulse-spray
    - Decreases treatment time & total thrombolytic dose
  - Catheter-directed thrombolysis
    - Cross thrombosed segment with guidewire
      - Catheter across entire thrombosed segment
      - Typical dose of TPA 0.5-1 mg of TPA/h
      - Adjunctive 500-700 U Heparin/h through sheath
    - Lysis check after 12-24 h
    - Identify and treat underlying lesions
  - Mechanical thrombectomy
    - Aspiration via catheter/guide sheath
    - Hydrodynamic thrombectomy (AngioJet)
    - Rotational thrombectomy devices
  - Stent deployment
    - Displaces clot, immediately restore flow

Alternative Procedures/Therapies

- **Medical**
  - Supervised exercise program
  - Target risk factors: Smoking cessation, BP control, lipid lowering, aggressive diabetes management, diet/weight loss
- **Surgical**
  - Bypass
    - Prefer autologous vein over synthetic graft
    - Prefer above knee to below knee popliteal artery as distal bypass site
  - Arterial endarterectomy
    - Preferred management for CFA disease
    - May be adjunct to surgical bypass
  - Surgical thromboembolectomy
    - For acute limb ischemia (SVS IIb)
    - More rapid flow restoration in threatened limb
    - Subsequent bypass graft if needed
  - Amputation
    - Nonviable acutely ischemic limb or nonhealing wounds despite revascularization

POST PROCEDURE

Things to Do

- Consider lifelong antiplatelet therapy
  - Aspirin (81 mg or 325 mg)
  - Clopidogrel (75 mg daily)
- Close clinical follow-up; surveillance with ABIs

OUTCOMES

Complications

- Immediate/periprocedural complication(s)
  - Arterial dissection
    - May require stent placement if flow limiting
  - Distal embolization (~ 2%)
    - Higher incidence in chronic total occlusions
    - Treat with aspiration thrombectomy/thrombolysis
  - Access site complications
  - Catheter-directed thrombolysis
    - Sequelae of ischemic tissue reperfusion (e.g., compartment syndrome, rhabdomyolysis)
    - Hemorrhagic complications
      - Intracranial (~ 1%)
- Delayed complication(s)
  - Stent fracture
    - Frequent in femoropopliteal segment (~ 10-20%)
      - Artery subject to extreme mechanical forces
  - In-stent restenosis/occlusion
    - Due to intimal hyperplasia
    - May be decreased with drug eluting stent

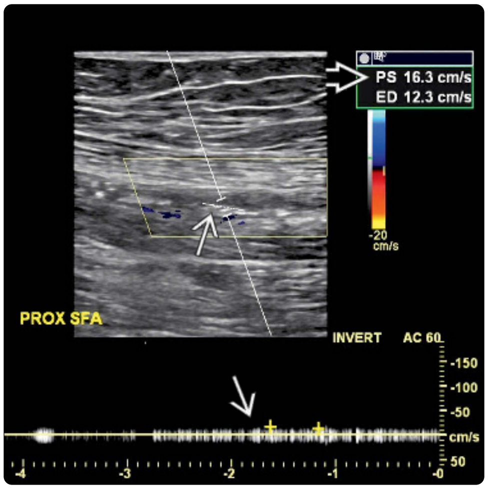
Expected Outcomes

- **General**
  - Greatly influenced by anatomic location, disease extent, inflow and outflow quality, occlusion vs. stenosis
- **Femoropopliteal lesions**
  - High initial technical success
    - Stenosis: 91%; occlusions: 83%
  - Worse outcomes in complex/long lesions, occlusions
  - Better outcomes with 1° stenting than PTA
    - Improved outcomes of covered stents vs. noncovered
  - Better outcomes with DCB than standard PTA
    - DCB 1° patency 65-90% at 1 year
- **Infrapopliteal lesions**
  - Technical success: ~ 90%
  - Goal is typically limb salvage in CLI
    - 2-year limb salvage rate: 86%
  - Long-term patency not as relevant
    - 2-year patency rate: 42%
  - Need to establish in-line flow to affected angiosome for reliable wound healing in CLI patients
- **Catheter-directed thrombolysis**
  - SVS I: 90-100% success rate

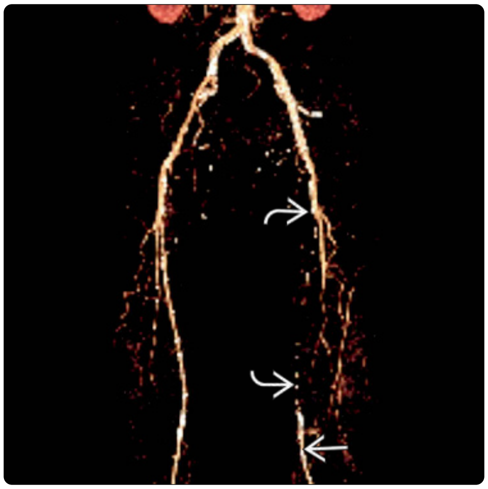
SELECTED REFERENCES

1. Naghi J et al: New developments in the clinical use of drug-coated balloon catheters in peripheral arterial disease. Med Devices (Auckl). 9:161-74, 2016

SFA Revascularization (Color Doppler Evaluation)

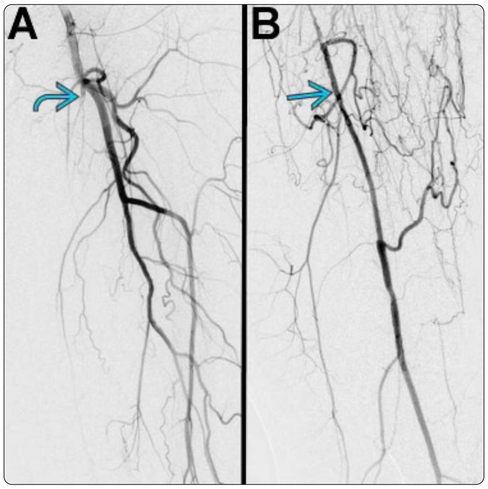


SFA Revascularization (Initial CTA Evaluation)

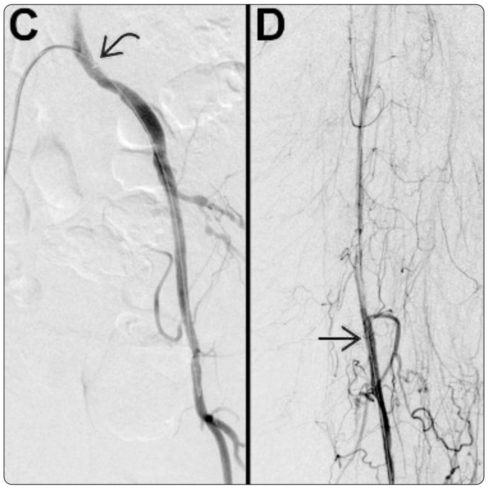


(Left) *Color Doppler US in a patient who presented with acute worsening of her left leg claudication shows only trace flow → in the superficial femoral artery and a markedly diminished peak systolic velocity ⇨, consistent with SFA occlusion.* **(Right)** *CTA of the pelvis and lower extremities was also obtained. 3D coronal reformation from that examination confirms the left SFA occlusion ↪. There is reconstitution of the above-knee popliteal arterial segment →.*

SFA Revascularization (Lower Extremity DSA)

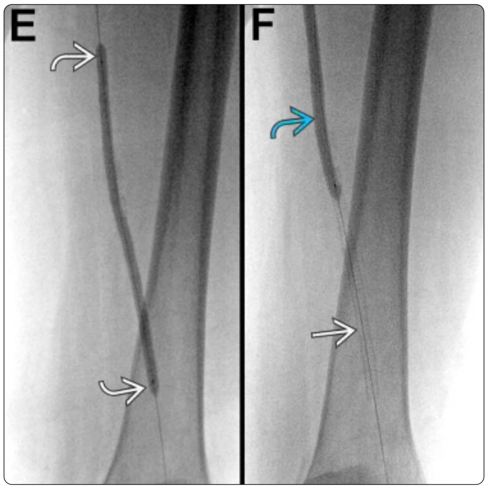


SFA Revascularization (Catheter/Guidewire Passage)

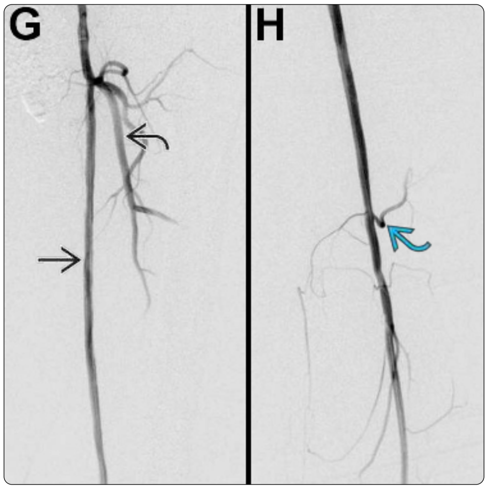


(Left) *(A) Via a right femoral artery access, a catheter was placed over the aortic bifurcation into the left common femoral artery. DSA shows proximal SFA occlusion ↪ with (B) reconstitution of the above-knee the distal SFA → via extensive collaterals supplied by the profunda femoris.* **(Right)** *(C) A curved sheath ↪ was advanced from left common iliac to common femoral artery level. (D) The SFA occlusion was crossed and a guidewire was placed into the popliteal artery →.*

SFA Revascularization (Angioplasty & Stenting)



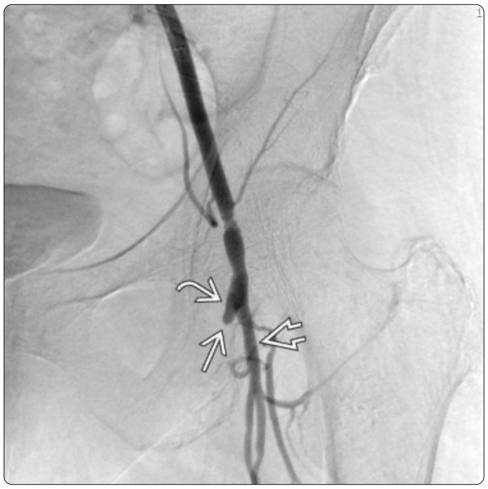
SFA Revascularization (Poststenting DSA)



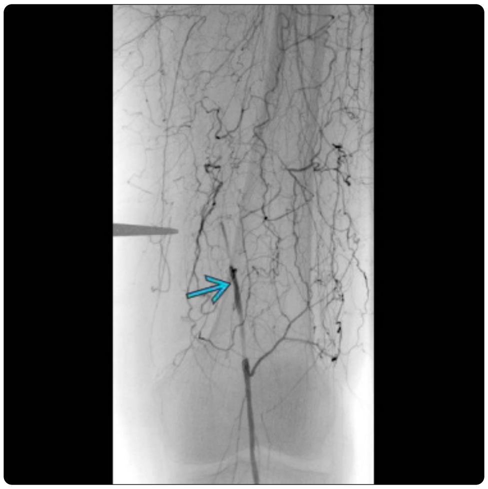
(Left) *(E) The occluded SFA was initially angioplastied with a 5-mm diameter balloon ↪ as an adjunct for subsequent covered stent → placement (F). Post-deployment angioplasty ↪ was performed to optimally distend the stents. Long segment and total occlusions typically respond poorly to angioplasty alone.* **(Right)** *(G) Poststenting DSA shows patency restored to the SFA → with a preserved profunda femoral artery ↪. (H) Distally, the stent terminates above the knee joint, and the large collateral ↪ is preserved.*

(Left) *One year after fem-pop bypass graft placement, this patient developed acute left lower extremity pain associated with mild numbness in the toes and weakness. Arterial pulses were not detectable. This is Rutherford class IIb (immediately threatened) acute limb ischemia. Note the bypass graft is only patent at its origin* ↷ *with acute cutoff* ➡. *The profunda femoris is patent* ⇨. **(Right)** *Angiogram more distally shows reconstitution of the above the knee popliteal artery* ⇨ *by collaterals.*

Thrombolysis of Femoral-Pop Bypass Graft (Initial Thrombosis)

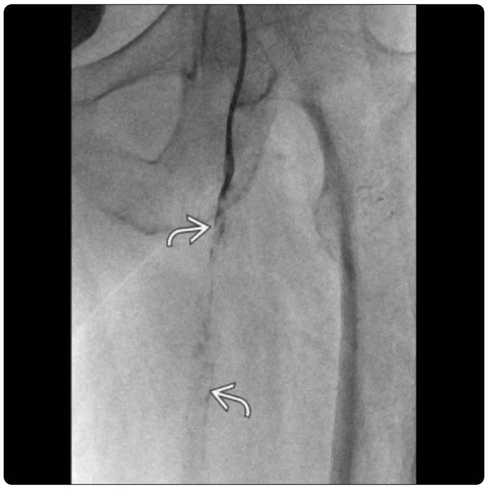


Thrombolysis of Femoral-Pop Bypass Graft (Initial Thrombosis)

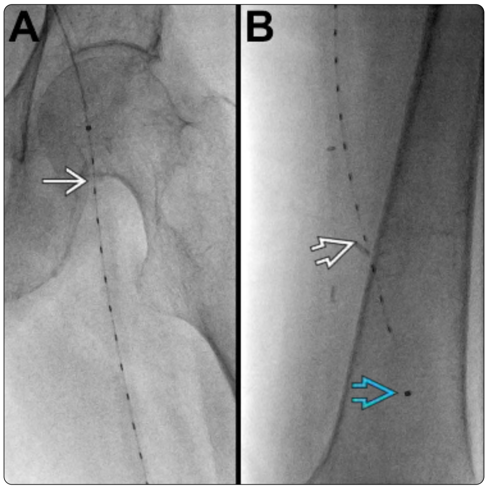


(Left) *The occluded fem-pop bypass graft was cannulated with a gentle injection showing clot throughout the bypass* ↷. **(Right)** *An EkoSonic thrombolysis catheter was placed throughout the clotted bypass graft from its origin* ➡ *(A) into the clot extending beyond the distal anastomosis* ⇨ *just into the patent portion of the above the knee popliteal artery* ⇨ *(B).*

Thrombolysis of Femoral-Pop Bypass Graft (Graft Cannulation)

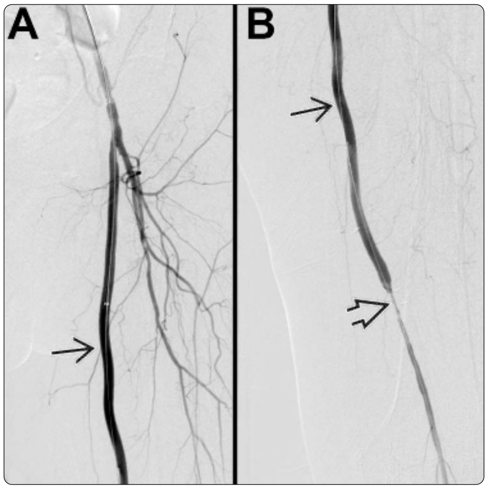


Thrombolysis of Femoral-Pop Bypass Graft (Catheter-Directed Thrombolysis)

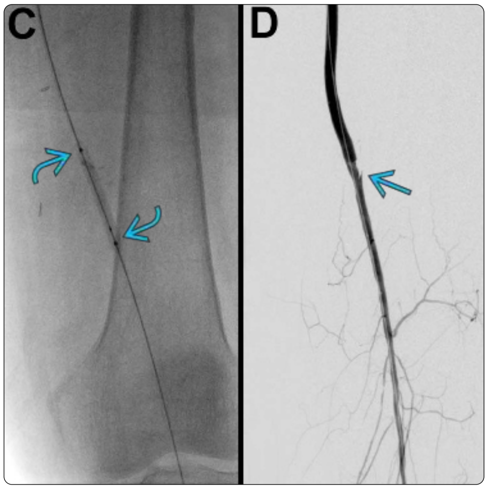


(Left) *After overnight TPA administration, repeat angiogram showed no residual clot in the bypass graft* ➡ *but severe stenosis at the distal anastomosis* ⇨, *a common site of underlying stenoses in bypass grafts.* **(Right)** *After balloon dilation of this stenosis* ↷ *(C), follow-up angiogram (D) shows no residual stenosis and a small non-flow limiting dissection* ➡.

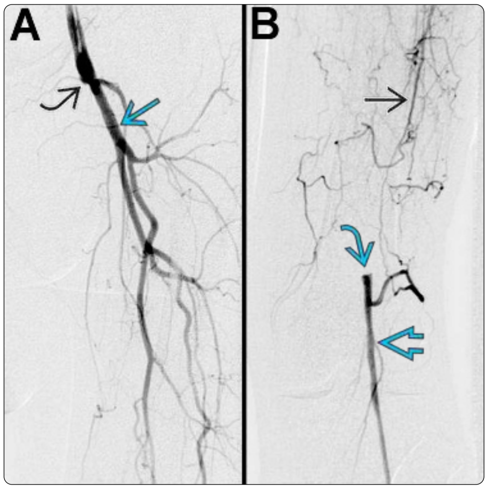
Thrombolysis of Femoral-Pop Bypass Graft (Underlying Anastomotic Stenosis)



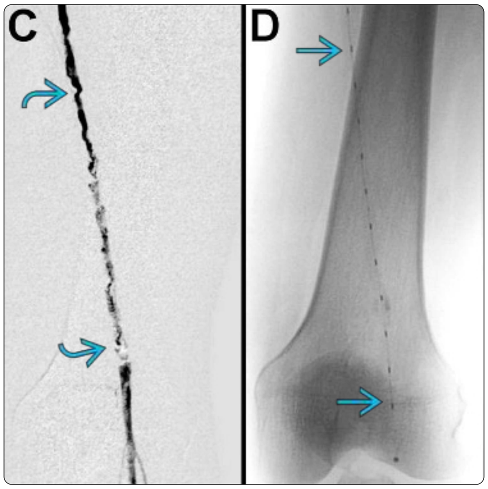
Thrombolysis of Femoral-Pop Bypass Graft (Angioplasty of Stenosis)



Acute Embolic Occlusion of SFA (Initial Angiogram)

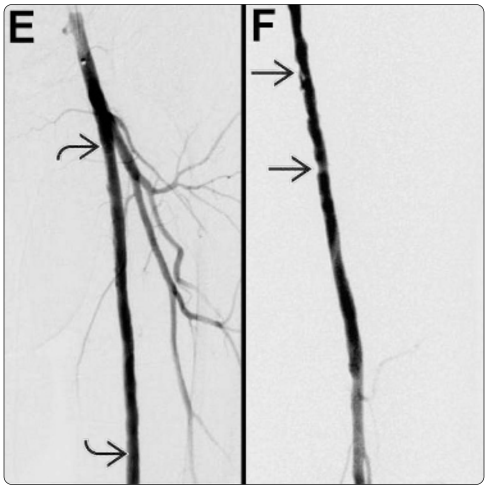


Acute Embolic Occlusion of SFA (Catheter-Directed Thrombolysis)

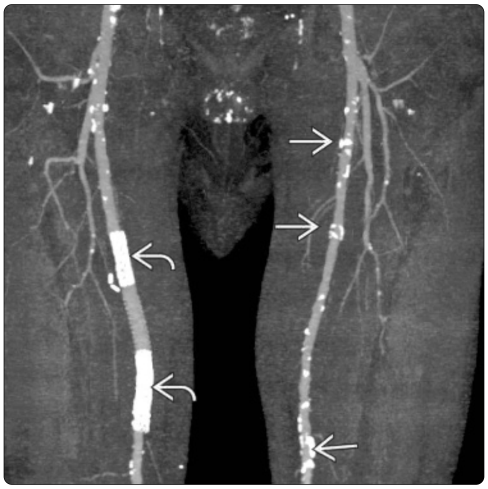


(Left) *This patient presented with acute left leg ischemia. (A) DSA shows occlusion of the SFA at the origin* ↷ *with filling of the profunda femoral artery* → *. (B) Poorly formed collaterals* → *reconstitute the above-knee segment of the popliteal artery* ↷ *, below a meniscoid filling defect* ⇨ *that is typical of an embolus.* **(Right)** *(C) Injection from a catheter placed within the occluded SFA shows thrombus* ↷ *throughout the occlusion. (D) An EKOS infusion catheter* → *was placed and thrombolysis was initiated.*

Acute Embolic Occlusion of SFA (Post Thrombolysis)

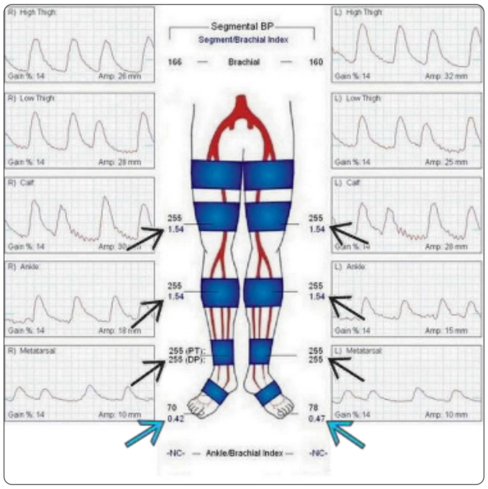


Acute Embolic Occlusion of SFA (Follow-Up)

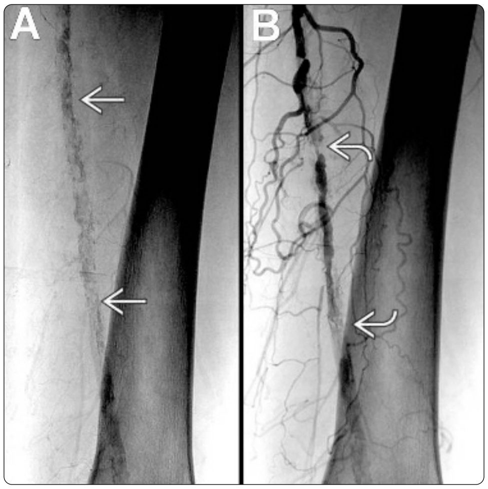


(Left) *(E) Twelve hours after initiating thrombolysis, patency was restored* ↷ *. (F) Scattered luminal irregularity* → *in the distal SFA is consistent with mild underlying atherosclerotic disease.* **(Right)** *Coronal CT reconstruction 1 month later shows scattered calcified atherosclerotic plaques* → *without significant stenosis. Contralateral SFA stents* ↶ *are seen. The meniscoid filling, poorly formed collaterals, and lack of underlying significant stenoses are all clues to the embolic nature of this occlusion.*

Severe SFA Disease (Falsely Elevated ABI)

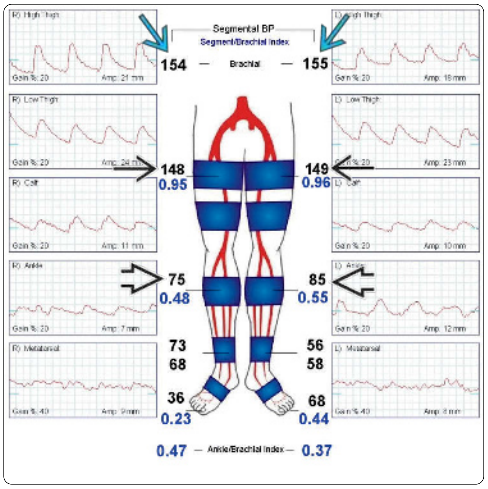


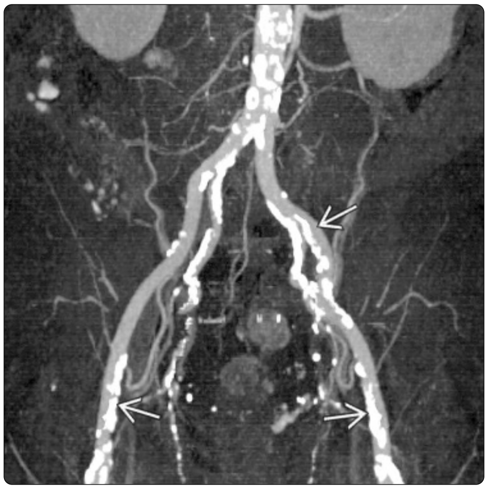
Severe SFA Disease (Angiographic Correlate)



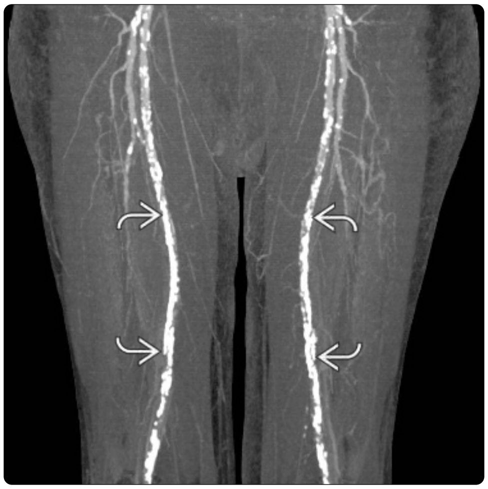
(Left) *While noninvasive testing is typically very sensitive in detecting lower extremity arterial disease, significant arterial calcification prevents adequate arterial compression, falsely elevating the ABI. A ratio > 1.3* → *is consistent with calcification and the study should be considered nondiagnostic. The toe brachial index* → *should be used instead.* **(Right)** *(A) Scout image of the left thigh confirms severe SFA arterial calcification* → *. (B) The angiogram shows a severely diseased SFA* ↶ *.*

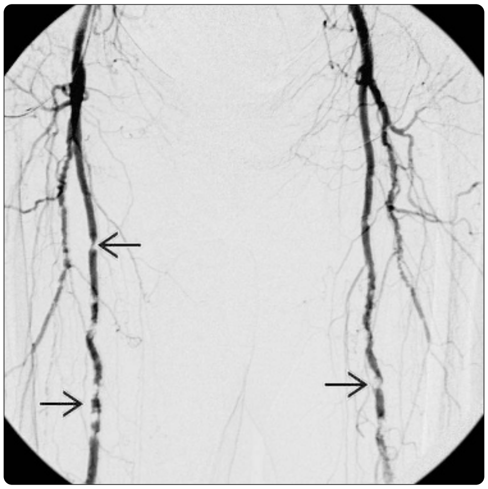
(Left) *The noninvasive arterial evaluation is a screening tool for lower extremity vascular disease. Its various components include segmental limb pressures and the ankle-brachial index. This study shows patent aortoiliac inflow* ⇨ *with bilateral drop in systolic pressures between the high thigh* ⇨ *and upper calf* ⇨ *consistent with bilateral SFA disease.* **(Right)** *CTA of the pelvis shows extensive vascular calcifications* ➡ *but confirms patent aortoiliac inflow.*


Bilateral SFA Disease (Segmental Limb Pressures & ABI)

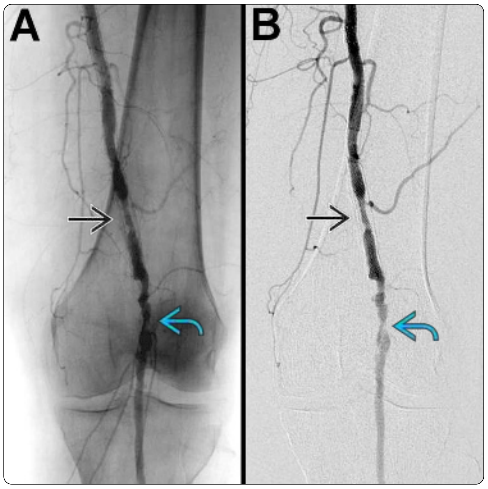

Bilateral SFA Disease (CTA)

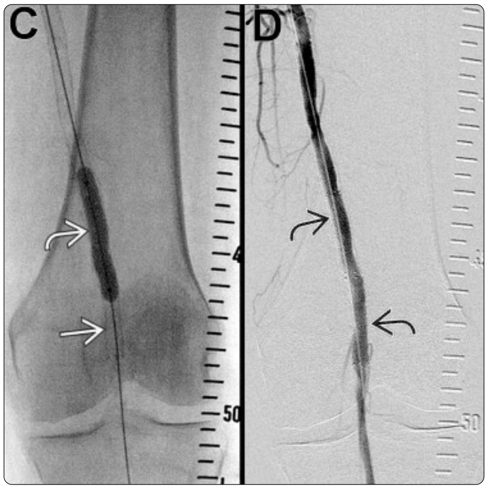
(Left) *CTA at thigh level shows extensive calcifications and multifocal stenoses or occlusions* ➡ *of the mid and distal SFAs bilaterally. The CTA correlated well with the noninvasive evaluation while additionally providing a map of arterial anatomy for preprocedure planning.* **(Right)** *DSA of the proximal portion of both SFAs confirms multifocal severe stenoses* ⇨*. DSA is typically reserved when endovascular intervention is planned.*


Bilateral SFA Disease (CTA)

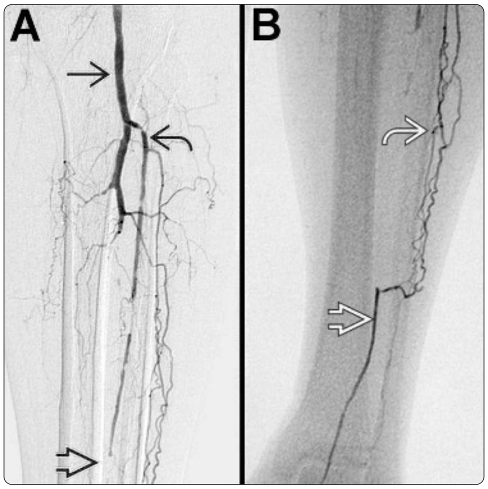

Bilateral SFA Disease (DSA)

(Left) *(A) Native and (B) subtracted DSA images are shown in a patient who had recurrent limb ischemia 2 years after stenting of distal-SFA chronic total occlusion. In-stent stenosis* ⇨ *is present, in addition to stenotic disease* ⇨ *in the native popliteal artery.* **(Right)** *(C) Balloon angioplasty* ➡ *was used to treat the in-stent stenosis. This was followed by stent placement* ➡ *in the diseased popliteal artery. (D) DSA afterward shows restoration of a normal luminal caliber* ⇨*.*

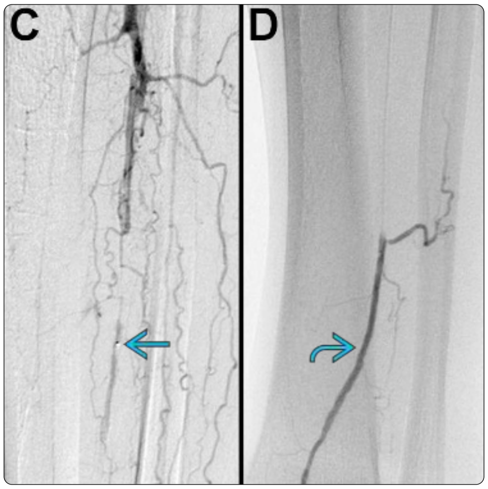

Balloon Dilation of In-Stent Intimal Hyperplasia (Initial Imaging)


Balloon Dilation of In-Stent Intimal Hyperplasia (Post Intervention)

Limb Salvage (Initial Angiogram)

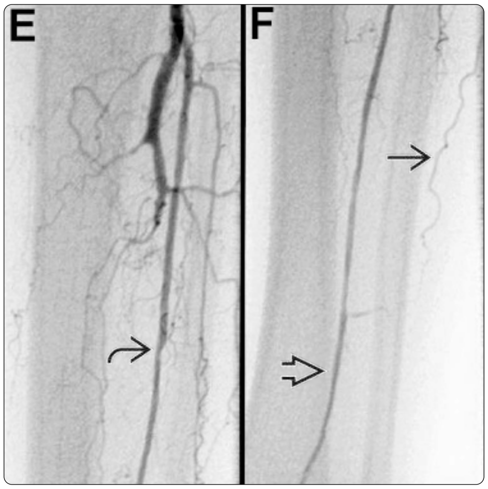


Limb Salvage (Microcatheter Advancement)

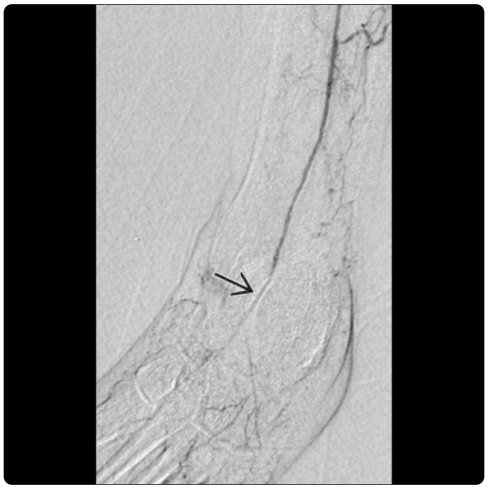


(Left) *(A) Left calf DSA in a patient with a nonhealing ischemic foot ulcer shows a patent popliteal → artery. The anterior tibial artery is patent proximally ↪, occluded in the mid-calf ⇨, but (B) reconstituted distally ➡ via collaterals ↪. The peroneal and posterior tibial arteries are occluded.* **(Right)** *(C) After catheterizing the proximal anterior tibial artery, a microcatheter → was successfully advanced across the occlusion (D) to a patent portion of the vessel ↪.*

Limb Salvage (Post Angioplasty)

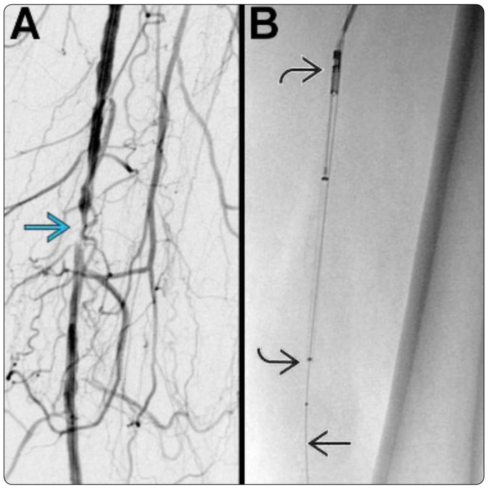


Limb Salvage (Distal Runoff)

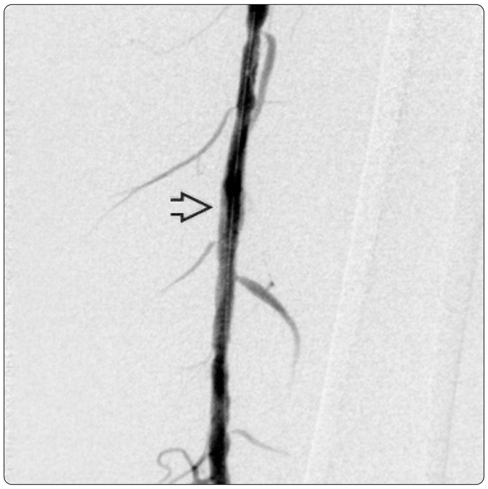


(Left) *(E) Angioplasty of the occluded anterior tibial artery was performed using a 3-mm diameter balloon. DSA afterward shows a patent artery proximally ↪ and (F) distally ⇨. With in-line flow restored, collaterals → are now only partially opacified.* **(Right)** *DSA of the ankle and foot shows the continuation of the anterior tibial artery as a patent dorsalis pedis artery →. Successful limb salvage interventions restore distal perfusion for long enough to allow healing to occur; long-term patency is not required.*

Atherectomy of SFA (Directional)

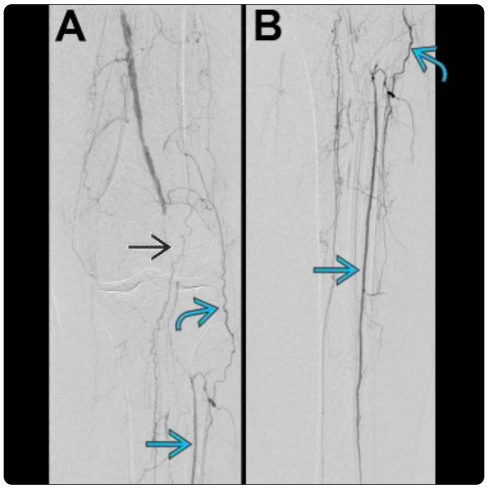


Atherectomy of SFA (Post Debulking)

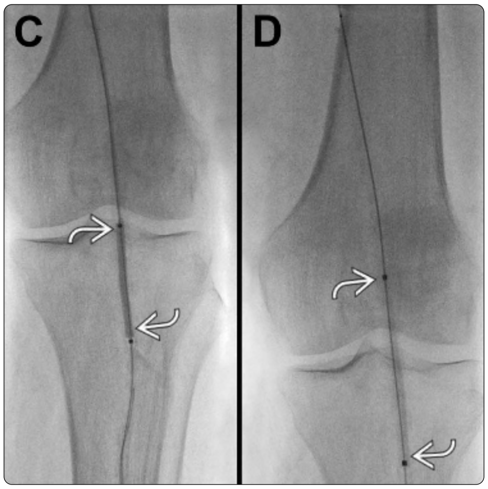


(Left) *(A) Severe, focal stenosis → is present in the distal left SFA. (B) After crossing the lesion with a 0.014" microwire →, a directional atherectomy device ↪ has been positioned for treatment.* **(Right)** *After atherectomy, a normal luminal caliber ⇨ has been restored at the site of the stenosis as a result of debulking of the atheromatous plaque. Atherectomy can be used for focal lesions or those in areas that do poorly with stenting (e.g., popliteal artery). Embolic protection device use should be considered when performing atherectomy.*

(Left) *This patient presented with nonhealing foot ulcers. (A) Initial angiogram shows occlusion of the popliteal artery → with reconstitution of the peroneal artery → via geniculate collaterals ↷. (B) The peroneal artery is the dominant below-knee run-off vessel.* **(Right)** *The occluded popliteal artery was cannulated and an over-the-wire balloon angioplasty ↷ was performed with 3-mm (C) and 4-mm (D) balloons.*

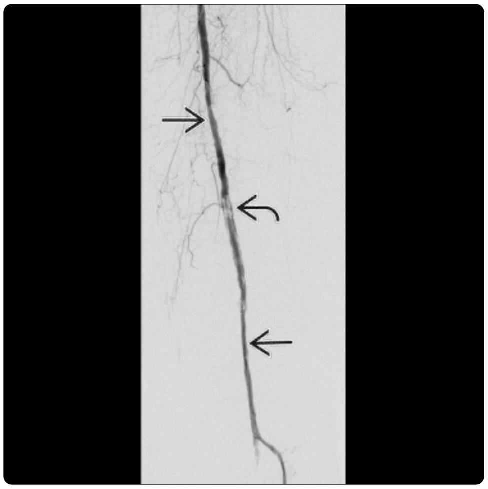


Delayed Complication: Popliteal Artery Dissection (Initial Angiogram)

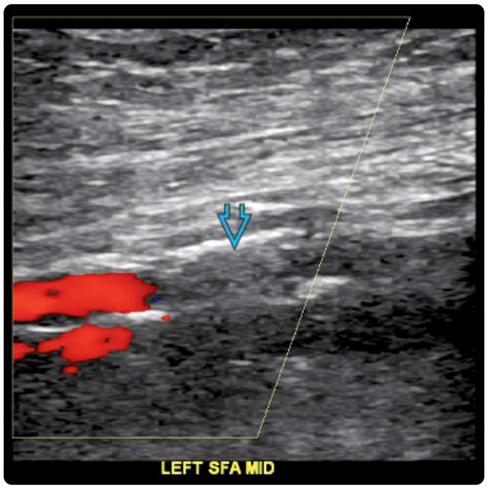


Delayed Complication: Popliteal Artery Dissection (Angioplasty)

(Left) *Repeat angiogram shows patency, but irregularity, of previously occluded popliteal artery →. A focal short segment dissection ↶ results in severe luminal narrowing in the mid popliteal artery.* **(Right)** *The patient returned 3 days post procedure with acute limb ischemia manifesting as a cold leg with rest pain. Ultrasound shows thrombosis within the mid SFA ⇨.*

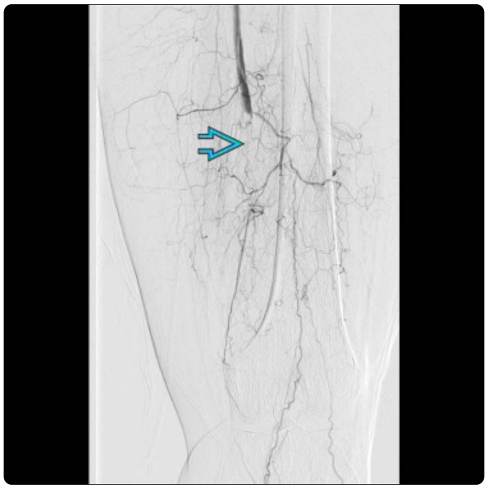


Delayed Complication: Popliteal Artery Dissection (Post Angioplasty)

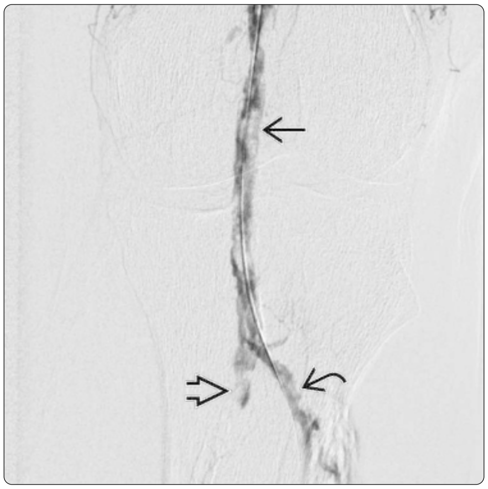


Delayed Complication: Popliteal Artery Dissection (Day 3 SFA Thrombosis)

(Left) *Angiogram demonstrates complete occlusion of the mid SFA ⇨. No appreciable below the knee flow was seen. While stents should generally be avoided behind the knee, a flexible stent should have been considered in this case of flow-limiting dissection.* **(Right)** *48 hours of TPA infusion failed to restore in-line flow to the foot. Note the clots throughout the popliteal artery → extending into the AT ↶ and tibioperoneal trunk ⇨. The patient subsequently underwent an above the knee amputation.*

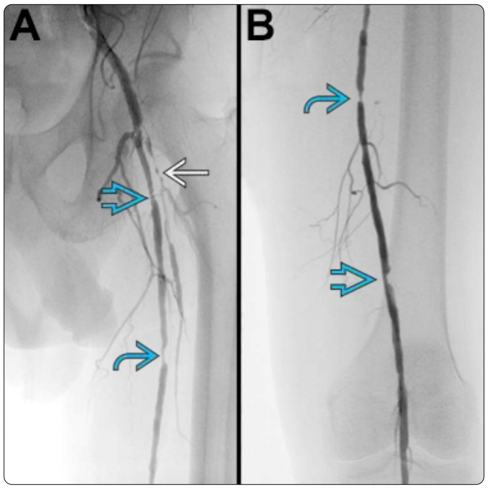


Delayed Complication: Popliteal Artery Dissection (Day 3 Angiogram)

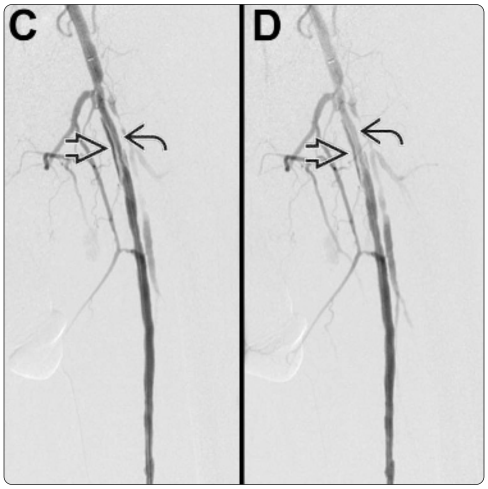


Delayed Complication: Popliteal Artery Dissection (Failed Thrombolysis)

Acute Complication: Dissection (Initial Angiogram)

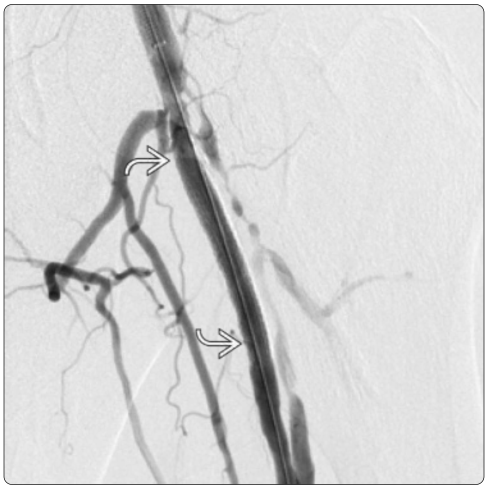


Acute Complication: Dissection (Post Angioplasty)

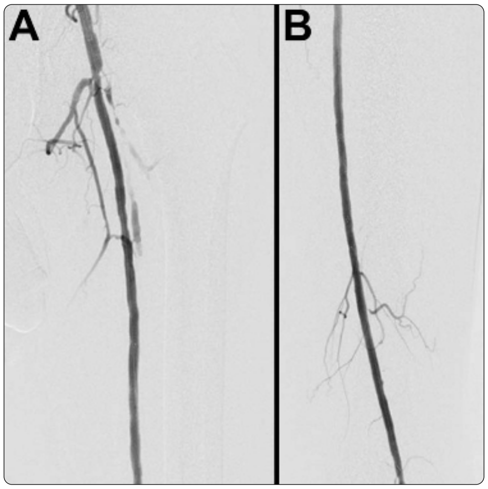


(Left) *Angiogram performed in a patient with nonhealing foot wounds shows multifocal, moderate* ⇨ *to severe* ↪ *SFA stenoses. Additionally, the profunda femoris, which usually serves as a source of collateral supply, is severely diseased* ➡*. These multifocal but short segment lesions are classified as TASC B.* **(Right)** *After balloon angioplasty, a flow-limiting dissection is present in the proximal SFA. Note false lumen* ⇨ *and true lumen* ↪*.*

Acute Complication: Dissection (Stent Placement)

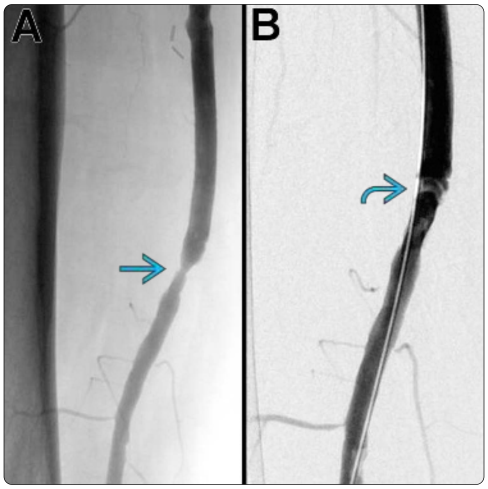


Acute Complication: Dissection (Final Result)

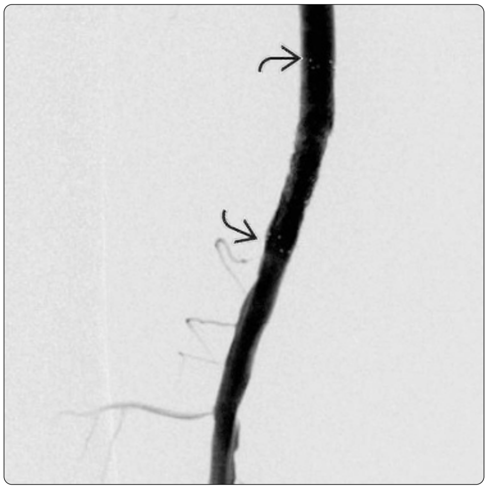


(Left) *Given the flow-limiting dissection, it was decided to place a 7-mm diameter Gore Viabahn stent* ➡ *across the dissection. Postdeployment angiogram shows good results with brisk flow through the stent. The ostium of the profunda femoris should not be covered, even in the presence of severe disease, in case subsequent profundaplasty is indicated.* **(Right)** *The final post stent and angioplasty angiogram shows near-normal caliber of the SFA.*

Delayed Complication: Stent Fracture (Angioplasty-Related Dissection)



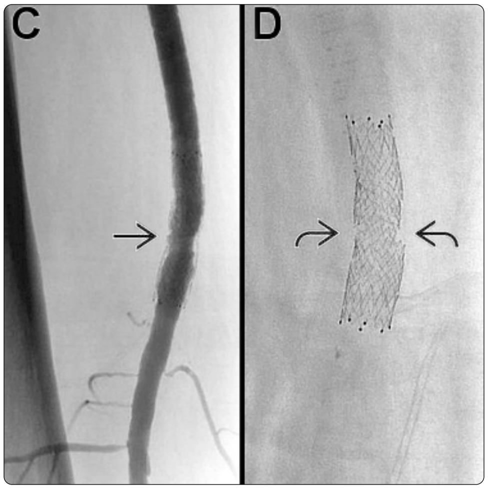
Delayed Complication: Stent Fracture (Stent Placement)



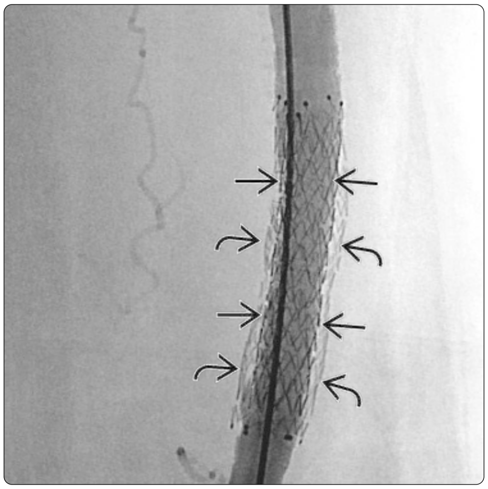
(Left) *(A) Angiogram of a patient with claudication shows a focal stenosis* →*. (B) DSA following angioplasty reveals an irregularity and possible dissection* ↪*.* **(Right)** *A self-expanding, noncovered stent* ↪ *was placed across focal dissection. Typically, short segment stenoses can be treated with PTA alone. In this case, a stent was necessary given the dissection.*

(Left) *One year after stenting, the patient developed painful blue toes. (C) DSA shows an irregular lumen ⇨ within the stent. (D) Scout image shows that the middle of the stent ↪ is fractured. This caused an irregular luminal surface, providing a locus for platelet and thrombus aggregation and subsequent distal embolization.* **(Right)** *A new stent ⇨ was placed inside of the fractured stent ↪, providing integrity and isolating the irregular endothelium. SFA stents are subject to tremendous mechanical forces.*

Delayed Complication: Stent Fracture

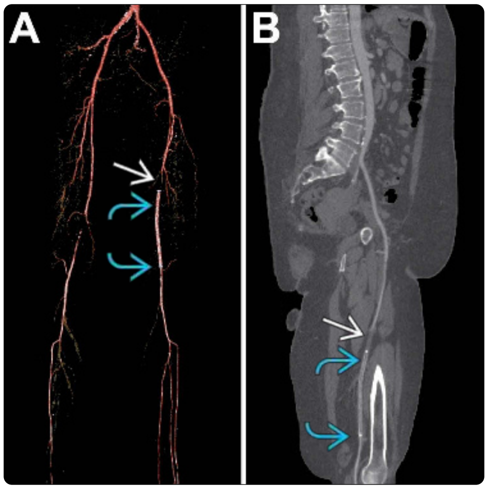


Delayed Complication: Stent Fracture (In-Stent Placement of Stent)

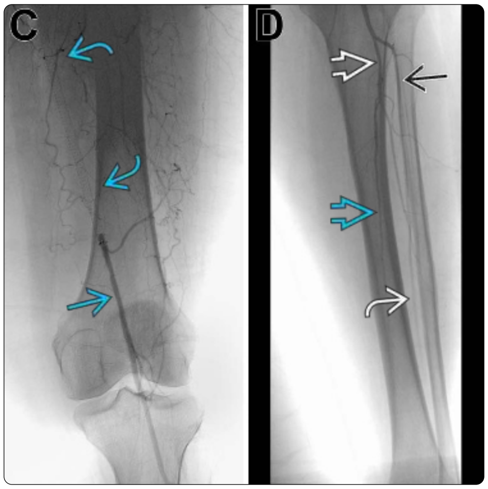


(Left) *CTA reformats in a patient with wounds on her 4th and 5th toes show occlusion of the stented portion of an SFA ↪ and occlusion of the native SFA ➡ proximal to the stent.* **(Right)** *Initial angiogram shows occlusion of the SFA stent ↪. The above-knee popliteal artery ⇨ is reconstituted via profunda femoris collaterals. There is 3-vessel runoff below the knee (AT ⇨, tibioperoneal trunk ➡, peroneal artery ➥, posterior tibial artery ⇨) but with faint opacification because of poor inflow.*

Acute Complication: Distal Embolization (Initial CTA)

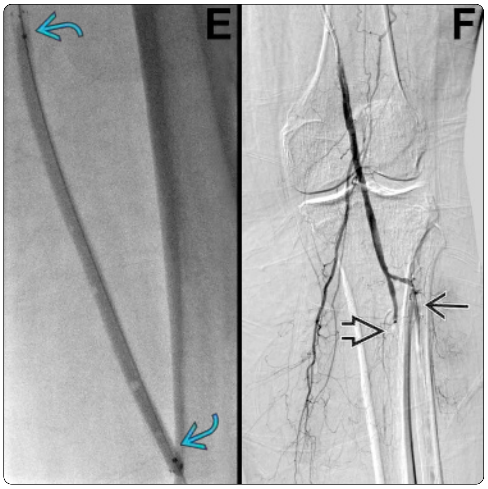


Acute Complication: Distal Embolization (Initial Angiogram)

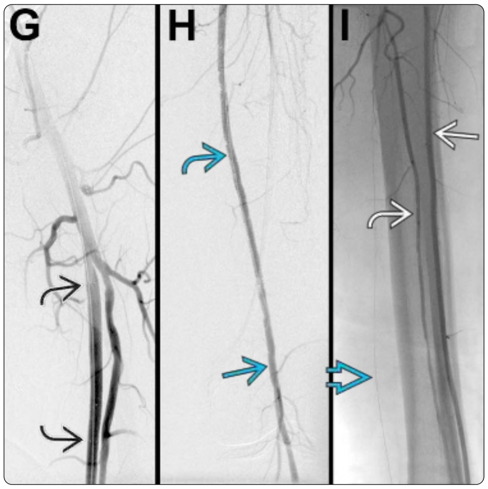


(Left) *After angioplasty ↪ of the in-stent thrombosis (E), angiography demonstrates acute cut-off of the AT ⇨ and PT trunk ⇨ (F). The patient developed acute pain and lost Doppler signals in the foot.* **(Right)** *On table TPA, suction thrombectomy and overnight CDT was coupled with SFA stenting of an iatrogenic dissection ↪. (G) Flow was restored into the SFA ↪ and (H) popliteal artery ⇨. (I) However, flow could not be restored to the posterior tibial artery (note wire ⇨). Peroneal artery ➥ & anterior tibial artery ➡ are noted.*

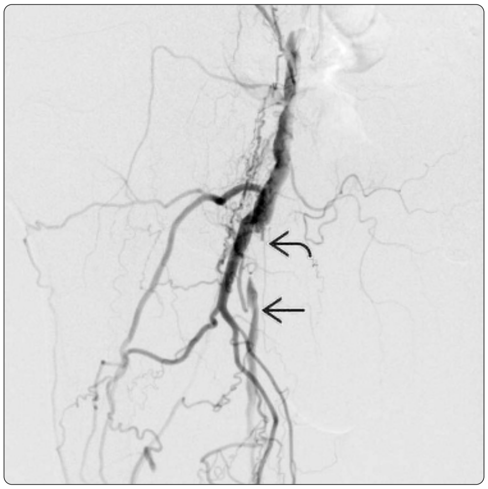
Acute Complication: Distal Embolization (Post Angioplasty)



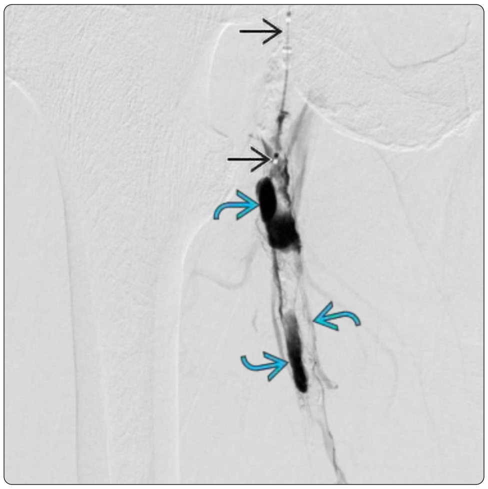
Acute Complication: Distal Embolization (Thrombectomy/Thrombolysis)



Intraprocedural Complication: Subintimal Intravasation (Initial Angiogram)

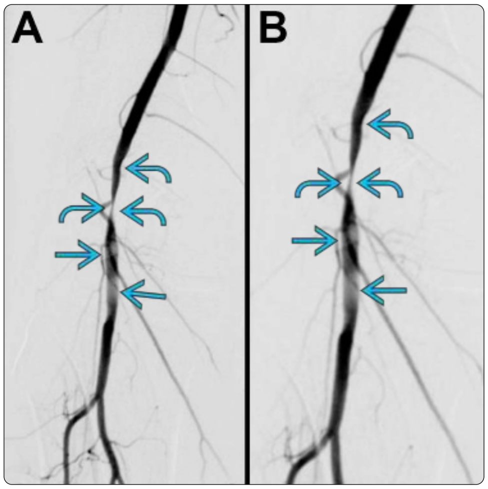


Intraprocedural Complication: Subintimal Intravasation (Failed Subintimal Passage)

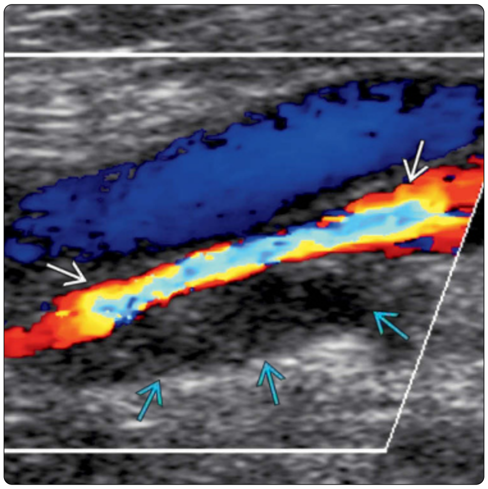


(Left) *Right common femoral artery DSA is shown in a patient with rest pain. Short segmental SFA-origin occlusion is present* ↪ *with reconstitution 2 cm distally* → *via profunda femoral artery collaterals.* **(Right)** *A hydrophilic guidewire and specialty catheter* → *were used to attempt crossing the chronic total occlusion. However, subintimal passage occurred, and with contrast injection there was intravasation into the perivascular soft tissues* ↪*. The procedure was halted.*

Cystic Adventitial Disease (DSA)

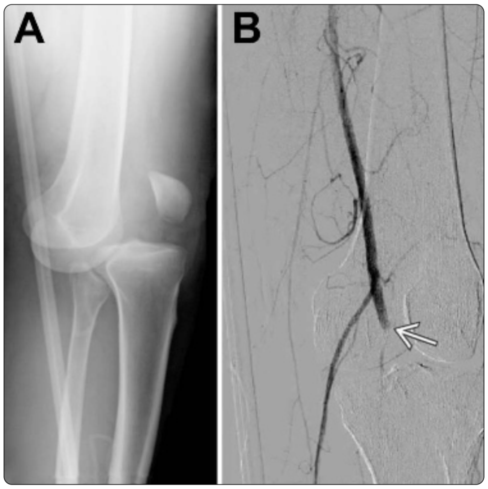


Cystic Adventitial Disease (US)

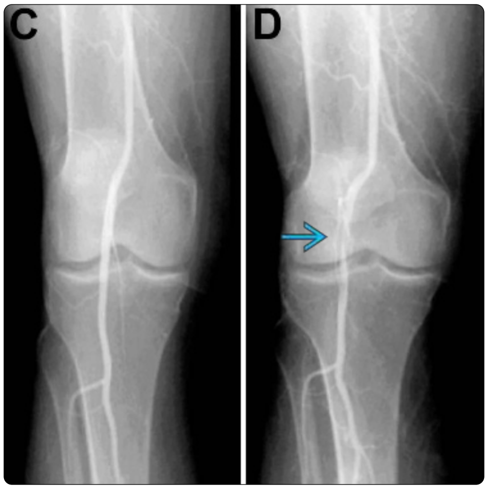


(Left) *Digital subtraction angiogram (A) and magnified view of the right popliteal artery (B) are shown in a young patient with claudication. Multifocal areas of stenosis are present, some seen en fos* → *and others in profile* ↪*.* **(Right)** *Ultrasound of the popliteal artery shows focal stenosis and aliasing* ➡ *caused by a low-density fluid* →*. These findings are consistent with cystic adventitial disease caused by mucinous cyst deposits in the adventitia. The popliteal artery of middle-aged men is most commonly affected.*

Popliteal Artery Injury from Posterior Knee Dislocation



Popliteal Artery Entrapment Syndrome



(Left) *A lateral radiograph (A) shows posterior knee dislocation in a patient with a cold left foot without palpable pulses. The angiogram (B) shows abrupt cutoff of the popliteal artery* ➡*. Limb salvage was possible via prompt surgical bypass.* **(Right)** *This young runner developed right calf claudication. An angiogram in the neutral (C) position demonstrates no anatomic abnormality. With plantar flexion (D) there is a focal occlusion of the popliteal artery* →*.*

KEY FACTS

PREPROCEDURE

- **Traumatic injuries requiring exclusion**
    - Pseudoaneurysm, intimal disruption, laceration
- **Cystic adventitial disease (CAD) treatment**
    - Treatment with percutaneous cyst aspiration to exclude luminal compression by cysts reported
- **Popliteal artery aneurysms (PAA) requiring exclusion**
    - All symptomatic aneurysms
        - Most common symptom: Acute limb ischemia
            - Due to either acute thrombosis of aneurysm or distal embolization of thrombus/atheroma
        - Mass effect symptoms due to popliteal vein or posterior tibial (PT) nerve compression
        - Aneurysm rupture is least common presentation
    - Asymptomatic aneurysm with diameter > 2 cm

PROCEDURE

- **PAA exclusion**
    - Must individualize treatment to patient/clinical scenario
        - Determine whether surgical revascularization or endovascular intervention more appropriate
    - Place catheter via access sheath; obtain DSA
        - Image entire popliteal artery, infrapopliteal runoff
    - Assess adequacy of proximal/distal attachment sites for covered stent placement
        - Use adequate stent length to span aneurysm
    - Deploy stent; perform gentle PTA at margins of stent
    - Assess stent position/no endoleak with DSA
- **Combined transcatheter interventions**
    - May need catheter-directed thrombolysis or surgical thrombectomy in certain scenarios
        - Patient must be able to tolerate additional period of ischemia during thrombolysis

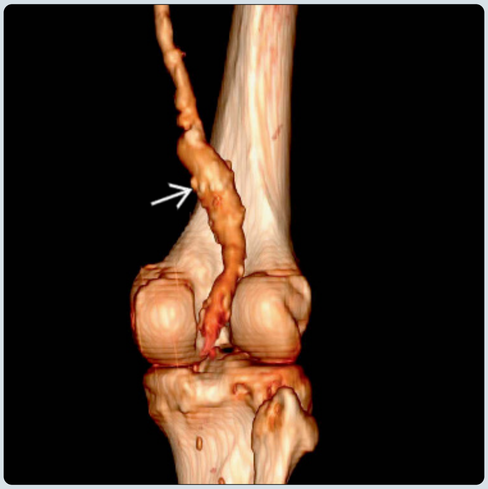
POST PROCEDURE

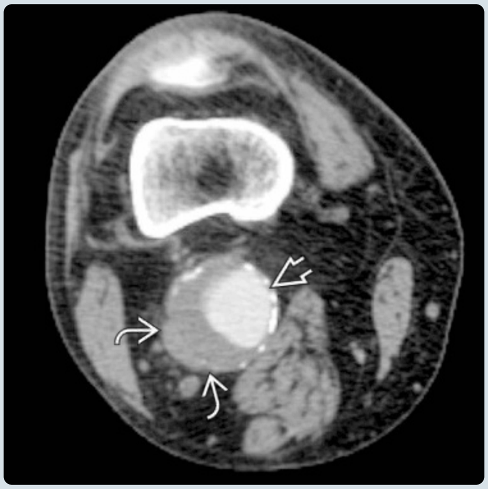
- 12-month primary patency rates after endovascular PAA exclusion: 60-87%
    - 24-month secondary patency rates: 78-98%

Popliteal Artery Aneurysm: Typical Appearance on CTA Imaging

Popliteal Artery Aneurysm: Typical Appearance on CTA Imaging

(Left) *Coronal 3D reformation of the right knee (posterior view) shows a fusiform popliteal artery aneurysm →. Symptomatic patients usually present with acute limb ischemia that is a result of either aneurysm thrombosis or distal embolization.* **(Right)** *A large popliteal artery aneurysm ⇨ can also compress adjacent structures, such as the popliteal vein ↪, as demonstrated on this axial CTA, & may cause calf swelling or DVT. Nerve compression by the aneurysm may result in posterior tibial neuropathy.*

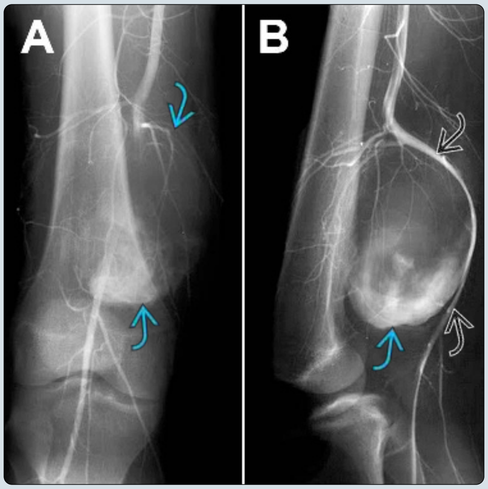


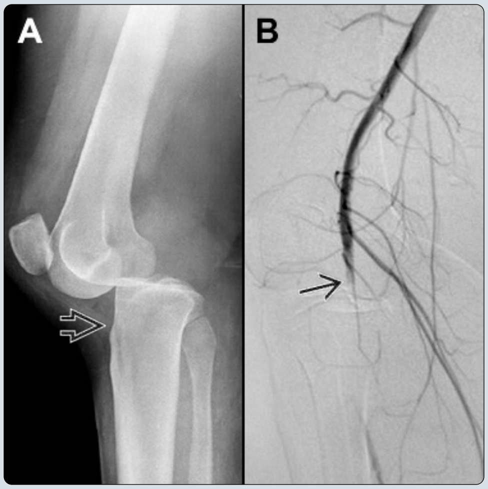


Popliteal Artery Pseudoaneurysm Caused by Penetrating Trauma

Posterior Knee Dislocation Causing Popliteal Artery Injury

(Left) *Because the popliteal artery is relatively superficial & spans the knee joint in the posterior fossa, it is particularly susceptible to trauma. (A) Anteroposterior & (B) lateral angiograms show a large pseudoaneurysm ↪ that displaces the popliteal artery ↪. This resulted from a penetrating injury.* **(Right)** *(A) Posterior knee dislocation ⇨ can cause intimal disruption, laceration, or transection of the popliteal artery. (B) DSA shows occlusion → of the popliteal artery at the level of the knee joint following the posterior knee dislocation.*





TERMINOLOGY

Definitions

- **Arterial laceration**: Complete or incomplete arterial transection
    - Most often due to penetrating or iatrogenic trauma
    - Popliteal artery particularly susceptible to trauma from posterior knee dislocation
        - May result in arterial laceration, intimal disruption
            - May lead to thrombosis, pseudoaneurysm
    - Clinical manifestations
        - Pulsatile bleeding or expanding hematoma
        - Absent distal pulses with cold, pale limb
        - Palpable thrill or audible bruit
    - Various imaging manifestations
        - Active contrast extravasation
            - May be due to partial arterial disruption or complete arterial transection
        - Complete occlusion of artery with absent runoff
        - Formation of traumatic arteriovenous fistula
        - Pseudoaneurysm formation
- **Cystic adventitial disease (CAD)**: Nonatherosclerotic disease characterized by compression of arterial lumen by subadventitial gelatinous cysts
    - Uncommon disease; mainly affects young males
        - M:F = 15:1
    - Exact pathogenesis poorly understood & controversial; various etiologic theories
        - Traumatic adventitial degeneration
        - Remnant mesenchymal rests during development
        - Cysts arise from synovium
    - Affects popliteal artery in 85-90% of cases
        - Also reported in common femoral, external iliac, axillary, brachial, ulnar, & radial arteries
        - Can also rarely affect venous structures
    - Clinical manifestations
        - Usually presents with sudden onset of claudication
            - May worsen with flexion of knee
- **Pseudoaneurysm (false aneurysm)**: Disruption of arterial wall with resultant contained rupture
    - May occur secondary to blunt or penetrating trauma
        - May also result in arterial laceration/transection
    - May be iatrogenic
        - Most commonly results from percutaneous arterial access; typically involves CFA
        - May be secondary to postoperative disruption of vascular surgical anastomosis
    - May rarely occur in association with skeletal osteochondromas
        - Popliteal artery most commonly affected
    - Major morbidity if unrecognized/untreated
        - Potential for pseudoaneurysm rupture
        - Distal thromboembolism with ischemia
- **Popliteal artery aneurysm (PAA)**: Abnormal arterial enlargement of ≥ 50% of normal vessel diameter
    - Most common aneurysm of native peripheral arteries
        - M:F ratio = 15:1
        - 60-70% bilateral
            - If bilateral PAAs present, 75% also have abdominal aortic aneurysm
    - Degenerative etiology > 90%
        - Other well-recognized causes
            - Behçet disease
            - Ehlers-Danlos syndrome
            - Marfan syndrome
            - Mycotic aneurysms
            - Trauma
    - Clinical manifestations
        - When symptomatic, usually presents with limb ischemia from aneurysm thrombosis/distal emboli
            - Emergent intervention often necessary
        - Pulsatile mass in popliteal fossa
        - Popliteal deep vein thrombosis (DVT) or posterior tibial (PT) neuropathy may sometimes occur
            - Caused by compression of adjacent vein &/or nerve by aneurysm
- **Persistent sciatic artery**: Embryonic lower extremity arterial supply fails to regress; congenital abnormality
    - In embryo, sciatic artery provides blood supply to leg
        - Normally replaced by primitive femoral artery
            - Arises from external iliac artery via capillary plexus; joins sciatic artery in knee region
        - If femoral artery not established as lower extremity inflow, may have persistence of sciatic artery
            - Internal iliac artery continues as sciatic artery; enters thigh posteriorly via sciatic foramen
            - Descends in posterior thigh adjacent to sciatic nerve sheath; continues as popliteal artery
        - Rare abnormality (incidence: 0.025-0.040%)
            - Bilateral in 25% of cases
    - 2 forms of persistent sciatic artery
        - Complete form (63-79% of cases)
            - Superficial femoral artery (SFA) hypoplastic or absent; typically ends in fork-like configuration
            - Sciatic artery is dominant arterial supply to leg
        - Incomplete form
            - Femoral artery & SFA are dominant supply to leg
            - Small persistent sciatic artery; may or may not communicate with popliteal artery
    - Clinical manifestations
        - Usually presents as aneurysm (25-58%)
            - Thrombosis, distal embolization, mass effect
        - May present as tender pulsatile buttock mass
            - Absent femoral pulse; palpable popliteal pulse
        - Very susceptible to atherosclerotic disease

Pertinent Infrainguinal Vascular Anatomy

- **Common femoral artery (CFA)**: Continuation of external iliac artery below inguinal ligament
    - Inguinal ligament corresponds to inferior epigastric/deep circumflex iliac artery origins
    - Bifurcates 2 cm below inguinal ligament into superficial & deep femoral arteries
- **SFA**: Extends from femoral bifurcation to adductor hiatus
    - Courses in adductor (Hunter) canal
        - Canal extends from femoral triangle to adductor hiatus (opening in adductor magnus muscle)
- **Deep (profunda) femoral artery**: Extends from femoral bifurcation into thigh musculature
    - Provides important collaterals; perforating branches resistant to atherosclerosis

- **Popliteal artery**
  - SFA becomes popliteal artery at adductor hiatus
  - Courses behind knee, between gastrocnemius heads
  - Bifurcates into anterior tibial, tibioperoneal trunk
- **Anterior tibial artery**
  - Passes anteriorly through intraosseous membrane
  - Becomes dorsalis pedis artery at ankle level
- **Tibioperoneal trunk**
  - Divides into peroneal & PT arteries
- **Peroneal artery**
  - Lies in deep posterior compartment; medial to fibula
  - May reconstitute dorsalis pedis artery
- **PT artery**
  - Supplies posterior compartment of calf
    - Distally forms plantar arch of foot

PREPROCEDURE

Indications

- **Traumatic injuries** (e.g., pseudoaneurysms, intimal disruption, laceration, active bleeding)
  - Must determine whether surgical revascularization or endovascular intervention more appropriate
    - Endovascular intervention may be inappropriate in small-caliber arteries
      - e.g., infrapopliteal arteries
    - Surgery may be higher risk in some situations
      - e.g., localized arterial injury amenable to covered/noncovered stent
  - Continued expansion is typical of pseudoaneurysm; resultant high rupture risk
    - Uniformly requires exclusion/repair
    - Treatment depends on size/location/morphology of pseudoaneurysm; various options
      - Percutaneous thrombin injection
      - Covered stent placement
      - Open surgical repair
- **CAD**
  - Usually needs revascularization instead of exclusion
    - Cysts may compress lumen, limiting arterial flow
      - Artery may become completely occluded
      - May cause degeneration of media
    - Typically treated with surgical cyst resection & vascular bypass or endarterectomy
      - Most durable outcomes seen with surgery
  - Treatment with percutaneous cyst aspiration to exclude luminal compression by cysts reported
    - Early recurrence rate of 10%
- **PAA**
  - All symptomatic aneurysms
    - Acute limb ischemia
      - Due to thrombosis of aneurysm (40%)
      - Due to distal emboli (25%)
      - Rupture least common (< 2%)
    - Compression of adjacent nerve or vein (10%)
      - Calf swelling, DVT
      - PT neuropathy
  - Asymptomatic aneurysm with diameter > 2 cm
    - 14-24% likelihood of becoming symptomatic
    - 68% progress to complications within 5 years
  - Untreated aneurysms associated with significant risk of limb loss in up to 30-40% of patients
    - Must closely follow untreated patients
      - Counsel patients as to risk of nontreatment
- **Persistent sciatic artery**
  - Requires exclusion if aneurysmal dilation present
    - High complication risk if aneurysm untreated
      - Limb ischemia from thrombosis, embolization
    - May require femoropopliteal bypass if persistent sciatic artery is dominant arterial supply of leg

Contraindications

- History of severe contrast allergy/anaphylaxis
- Severe renal dysfunction
- Uncorrectable coagulopathy
- Stent placement across lesion crossing/involving joints (e.g., knee, hip) remains controversial
  - Higher likelihood of stent compression/fracture
    - May require secondary interventions to maintain long-term patency
- Treatment of critical limb ischemia due to aneurysm thrombosis/distal embolization must be individualized
  - May need emergent surgical revascularization
    - Typically restores perfusion more quickly than thrombolysis & endovascular aneurysm exclusion
    - Threatened but salvageable limb if treated promptly, no sensory loss/muscle weakness
      - Society for Vascular Surgery category 2a
  - May be unable to tolerate prolonged ischemic time

Preprocedure Imaging

- CTA
  - Excellent delineation of arterial anatomy & pathology
  - Similar accuracy to DSA
- MRA
  - Excellent delineation of arterial anatomy & pathology
    - Contrast & noncontrast techniques available
- US
  - Color Doppler US useful for arterial screening
    - Aneurysm evaluation/characterization
  - May include noninvasive arterial evaluation
    - Evaluation of flow hemodynamics
- DSA
  - Limited role in preprocedure evaluation
    - Primary imaging guidance during intervention
  - Considered gold standard

Getting Started

- Things to check
  - Clinical history & physical examination
    - Appropriate procedure indications
    - Comprehensive cardiovascular evaluation
      - Detailed pulse examination/Doppler evaluation
    - Current medications
      - Any anticoagulants/antiplatelet agents
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - Complete blood count
      - Platelet count > 50,000/μL

    - Coagulation profile
      - International normalized ratio ≤ 1.5
      - Normal prothrombin time, partial thromboplastin time
  - **Limit oral intake**: NPO for 8° prior to procedure
    - If moderate sedation/general anesthesia planned
    - Take any oral medications with sip of water
  - Informed procedure & sedation consent obtained
- Medications
  - Agents for moderate sedation
    - Fentanyl & midazolam typically used
  - Heparin
    - Various intraprocedural administration regimens
      - Bolus dose of 2,500-5,000 U; followed by infusion of 1,000 U/h
      - Loading dose of 50-100 U/kg; followed by continuous infusion of 15-25 U/kg/h
  - Vasodilator (e.g., nitroglycerin)
    - Typical bolus dose of 100 µg nitroglycerin
    - Prevents/treats catheter-induced vasospasm
  - 1-2% lidocaine local anesthesia
- Equipment list
  - Arterial access equipment
    - Micropuncture access kit
      - Micropuncture needle/microwire
      - Transitional dilator
    - 18-g arterial access needle
  - Access sheaths
    - 5- to 8-Fr vascular access sheath
      - Size depends on catheters/delivery systems
      - Permits catheter exchanges as necessary
    - Crossover access sheath (for contralateral access)
      - e.g., Ansel, Balkin sheaths
  - Catheters
    - Diagnostic catheter
      - Flush catheter (e.g., pigtail, Omni Flush)
      - Selective catheter (e.g., Davis, Simmons)
    - Coaxial 2.6- to 3.0-Fr microcatheter
      - Various proprietary options
    - Angioplasty (PTA) balloon catheter
      - Various sizes, configurations
      - May be used to postdilate self-expanding stent
  - Guidewires
    - Initial "starting" 0.035" guidewire
    - Angled or straight-tipped hydrophilic guidewire
      - Often beneficial for selective catheterization
    - Stiff guidewire (e.g., Amplatz, Rosen)
      - Stability when advancing/placing devices
    - 0.014-0.018" microwire
      - For use with microcatheter
    - Exchange-length guidewires may be needed
  - Embolic agents
    - Coils
      - Detachable 0.035" or 0.018" embolization coils
      - "Pushable" 0.035" or 0.018" embolization coils
    - Liquids
      - N-butyl cyanoacrylate TRUFILL (Cordis; Bridgewater, NJ)
      - Onyx (ev3 Neurovascular; Irvine, CA)
      - Thrombin (1,000 U/mL)
    - Plug occluding device
      - Amplatzer vascular plug (AGA Medical; North Plymouth, MN)
  - Stents
    - Noncovered self-expanding/balloon mounted
      - May be used for stent-assisted coiling
      - Various proprietary options
      - Have less of role in arterial exclusion interventions than covered stents
    - Covered self-expanding/balloon mounted
      - iCAST (Atrium Medical; Hudson, NH)
      - Fluency (Bard Peripheral Vascular; Tempe, AZ)
      - Viabahn (WL Gore; Newark, DE)

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Common femoral or proximal SFA lesion
    - Contralateral retrograde access
      - Place crossover access sheath into contralateral distal external iliac artery
  - Distal SFA or popliteal lesion
    - Ipsilateral antegrade access
      - Difficult with short CFA or obese patient
  - Infrapopliteal lesions
    - Ipsilateral antegrade access usually used

Procedure Steps

- **Obtaining access**
  - Determine whether ipsilateral antegrade vs. contralateral access more appropriate
    - Transfemoral arterial access used for infrainguinal endovascular interventions
  - Sterilely prepare/drape intended access site
  - Administer 1-2% lidocaine local anesthesia
  - Obtain arterial access; insert access sheath
  - **Placement of crossover sheath**
    - Requires placing guidewire over aortic bifurcation
    - Consider initially placing reverse-curve or Cobra catheter in distal aorta near bifurcation
      - Use catheter to direct guidewire into contralateral common/external iliac artery
    - Place catheter over guidewire into contralateral side
    - Exchange for stiff guidewire; remove catheter
      - Ensure guidewire tip in distal external iliac artery
    - Introduce crossover sheath over stiff guidewire
      - Position sheath tip in distal external iliac artery
  - **Placement of antegrade access sheath**
    - Ensure access needle tip enters CFA well above CFA bifurcation
      - Need adequate room to direct guidewire into SFA
    - Introduce guidewire via access needle
    - Guidewire often preferentially enters profunda femoral artery rather than SFA
      - Caudal needle trajectory directs guidewire into posteriorly coursing profunda femoral artery
    - If guidewire enters profunda femoral artery
      - Maintain guidewire position; remove needle
    - Place angled catheter (e.g., Kumpe) over guidewire

    - Slowly withdraw angled catheter while injecting contrast; identify SFA origin
        - ☐ Use catheter to direct guidewire into SFA
        - ☐ Angled-tip hydrophilic guidewire useful
- **General steps after securing access**
    - ○ Introduce flush/selective catheter via sheath
    - ○ Position catheter for initial DSA imaging
        - e.g., selective catheter in external iliac artery
    - ○ Inject contrast; obtain DSA images
    - ○ Review DSA; determine appropriate intervention
    - ○ Proceed to intervention
    - ○ Following intervention, obtain DSA
        - Document results/exclude complications
    - ○ Remove catheters/sheaths; obtain hemostasis
- **Transcatheter embolization (general)**
    - ○ Consider using coaxial microcatheter
        - Facilitates selective catheterization of smaller caliber arteries/branches
            - ☐ Permits superselective embolization
    - ○ Must avoid exclusion of critical branches arising in treatment/target embolization area
- **PAA exclusion**
    - ○ Advance catheter into mid to distal SFA
    - ○ Inject contrast; obtain DSA images
        - Image entire popliteal artery, infrapopliteal runoff
        - Analyze DSA images
            - ☐ Assess aneurysm morphology; determine appropriateness of endovascular exclusion
        - Assess adequacy of proximal/distal attachment sites for covered stent placement
            - ☐ Stent ends should terminate in nonaneurysmal, disease-free arterial segments
            - ☐ Need ~ 1-cm length proximal/distal seal zones
        - Ensure stent will not exclude any critical branches
    - ○ Administer heparin prior to intervention
    - ○ Choose appropriate covered stent for exclusion
        - Most operators prefer Viabahn endograft for endovascular repair
            - ☐ Self-expanding flexible nitinol stent
            - ☐ Polytetrafluorethylene lining of endograft with heparin-bonded surface
        - Oversize stent diameter by ~ 20%
            - ☐ Relative to proximal/distal attachment sites
        - Use adequate stent length to span aneurysm
            - ☐ Proximal & distal attachments of covered stent should be in disease-free arterial segments
        - Consider placing calibrated catheter across diseased segment & obtaining DSA via access sheath
            - ☐ Use DSA to determine appropriate stent length
    - ○ Advance guidewire & catheter across aneurysm
        - Position catheter tip distal to aneurysm
    - ○ Exchange for stiff guidewire
        - Leave guidewire indwelling; remove catheter
    - ○ Introduce covered stent over guidewire
        - Position stent using fluoroscopy
    - ○ Deploy stent while fluoroscopically monitoring
    - ○ Remove delivery system, leaving guidewire in place
    - ○ Introduce appropriate-sized angioplasty balloon
        - Should correspond to normal arterial diameter at proximal/distal attachment sites
    - ○ Perform gentle angioplasty at margins of stent
        - Distends stent at proximal/distal attachments
            - ☐ Helps to ensure seal at contact points
    - ○ Remove angioplasty balloon; leave guidewire in place
    - ○ Inject contrast via access sheath; obtain DSA
        - Confirm satisfactory stent position/no endoleak
    - ○ Remove guidewire & access sheath
    - ○ Obtain hemostasis
        - May use closure device or manual compression
- **Pseudoaneurysm exclusion/treatment**
    - ○ Iatrogenic access-related pseudoaneurysms should be treated with thrombin injection if appropriate
    - ○ Anastomotic or posttraumatic pseudoaneurysm management may be variable
        - Dependent on location, size, morphology
        - Surgical repair more appropriate in some cases
            - ☐ Large anastomotic pseudoaneurysms, particularly involving inguinal/popliteal levels
        - Endovascular repair often also appropriate
            - ☐ Placement of covered stent for exclusion
            - ☐ Transcatheter embolization with coils or liquid agents if narrow neck, solitary feeding branch
            - ☐ Stent-assisted coil embolization
    - ○ Pseudoaneurysms associated with osteochondromas (rare) require surgery rather than endovascular repair
        - Vascular repair/bypass & surgical resection of osteochondroma
- **Combined transcatheter interventions**
    - ○ May need concurrent catheter-directed thrombolysis or surgical thrombectomy in certain scenarios
        - Thrombosed aneurysm/distal embolization
            - ☐ Thrombolysis may delineate arterial runoff distal to thrombosed aneurysm; important information for surgical/endovascular exclusion
            - ☐ Pre-/intraoperative thrombolysis of thrombosed PAAs reported to have significantly improved 1° graft patency at 1 year
            - ☐ Patient must be able to tolerate additional period of ischemia during thrombolysis

Alternative Procedures/Therapies

- Surgical
    - ○ **Anastomotic pseudoaneurysms**
        - May require open surgical resection & repair
            - ☐ Pseudoaneurysm morphology/location impacts management strategy
            - ☐ Treatment must be individualized; some cases may be appropriate for endovascular intervention
    - ○ **CAD**
        - Cyst excision with preservation of arterial wall
        - Surgical resection of affected arterial segment & bypass with autologous venous interposition
        - Endarterectomy; resection of affected wall layers
    - ○ **Persistent sciatic artery**
        - Aneurysm resection, ligation
            - ☐ Complete form requires concurrent vascular bypass in order to maintain arterial inflow to leg
    - ○ **PAA**
        - Surgery remains mainstay of aneurysm treatment; different treatment options available
            - ☐ Surgical ligation & bypass

      - ☐ Aneurysmorrhaphy/aneurysm resection
  - ○ **Traumatic injury** (e.g., laceration, pseudoaneurysm)
    - Surgical bypass/revascularization
    - Primary repair of arterial wall defect
      - ☐ Mycotic pseudoaneurysms require surgical repair
      - ☐ Posttraumatic pseudoaneurysms with excessively wide neck may require surgery
      - ☐ Pseudoaneurysms causing mass effect (e.g., claudication, neuropathy, critical limb ischemia)
      - ☐ Arterial transections require surgical repair/bypass

POST PROCEDURE

Things to Do

- Consider lifelong antiplatelet therapy after stent placement
  - ○ Aspirin (81 mg or 325 mg)
  - ○ Clopidogrel (75 mg daily)
    - Typically administered for 6-12 weeks
- Close clinical follow-up
  - ○ Endovascular PAA repair may require secondary intervention to maintain patency
- Surveillance with noninvasive arterial evaluation or with imaging evaluation

OUTCOMES

Complications

- Most feared complication(s)
  - ○ Arterial thrombosis, distal embolization
  - ○ Arterial dissection
    - May require secondary stent placement
- Immediate/periprocedural complication(s)
  - ○ Access site complications
    - Higher incidence if intervention performed
      - ☐ Typically requires larger caliber access
    - Most common access site complications
      - ☐ Groin hematoma (3.0%); pseudoaneurysm (1.0%); arteriovenous fistula (0.2%)
  - ○ Allergic/anaphylactic reaction to contrast
  - ○ Contrast-induced nephropathy
- Delayed complication(s)
  - ○ In-stent stenosis/occlusion/thrombosis
    - Most frequently due to intimal hyperplasia
    - Thrombosis/occlusion may also be mechanical
      - ☐ Stent compression, altered flow hemodynamics across hip/knee joint
    - Stenoses typically occur at proximal/distal attachments of stent to native artery
      - ☐ May respond to angioplasty
      - ☐ May require extension of stent
    - Treatment of thrombosed stent may require thrombolysis to restore patency
      - ☐ Must evaluate for & treat any underlying lesion that may have caused thrombosis
  - ○ Stent fracture
    - Frequent in femoropopliteal segment (~ 10-20%)
      - ☐ Artery subject to extreme mechanical forces
    - May lead to eventual thrombosis/occlusion
      - ☐ May respond to combined thrombolysis & placement of new stent within fractured stent
    - Occurs more frequently with noncovered than with covered stents

Expected Outcomes

- **PAA exclusion**
  - ○ Reported 12-month primary patency rates after endovascular exclusion range from 60-87%
    - 24-month secondary patency rates: 78-98%
  - ○ Reported 12-month primary patency rates after surgical repair range from 78-100%
    - 24-month secondary patency rates: 82-100%
  - ○ Lower wound complication rate & shorter length of hospital stay with endovascular exclusion than surgery

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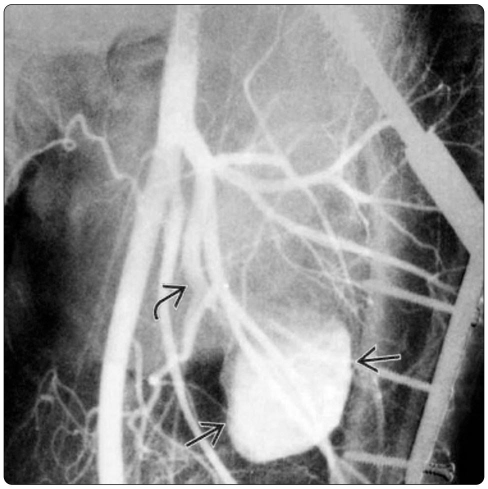
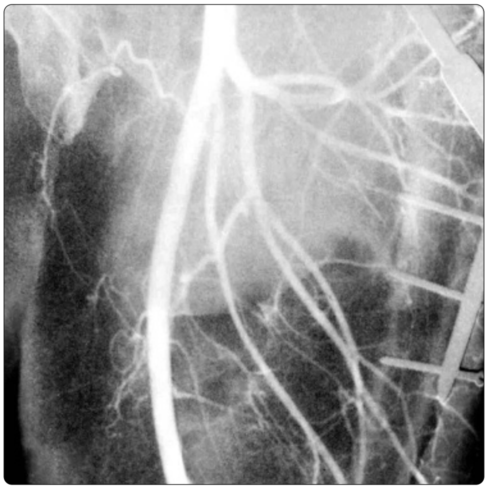
(Left) *A patient with a large thigh hematoma after open reduction & internal fixation of a left femur fracture underwent angiography. This shows a saccular pseudoaneurysm → arising from a branch ↷ of the profunda femoral artery.* **(Right)** *Microcatheter was placed in the pseudoaneurysm, & liquid thrombin was injected, successfully thrombosing the pseudoaneurysm & the profunda femoral artery feeding branch. Coil embolization of the feeding artery could have been performed instead.*

Iatrogenic Pseudoaneurysm: Initial Angiographic Evaluation

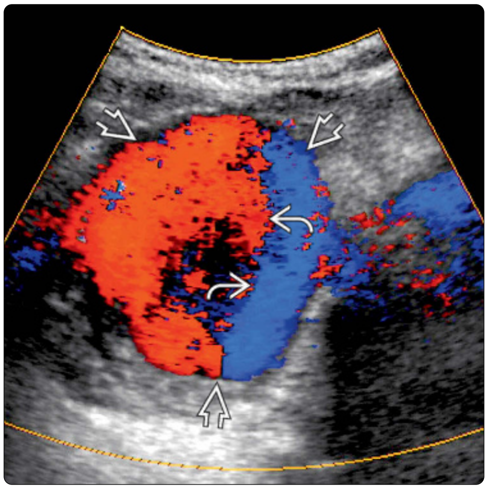


Iatrogenic Pseudoaneurysm: After Transcatheter Thrombin Injection

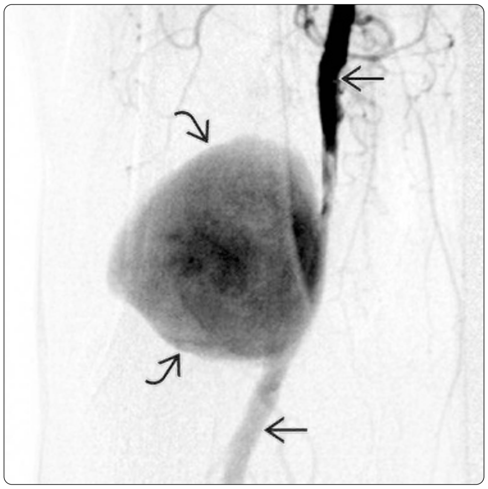


(Left) *Color Doppler US of the left popliteal artery was obtained in a patient with Ehlers-Danlos syndrome who presented with a pulsatile popliteal fossa mass. This shows a large vascular mass ⇨ with a yin-yang flow appearance ↷ that is typical of a pseudoaneurysm.* **(Right)** *DSA shows a saccular pseudoaneurysm ↷ arising from the popliteal artery →. In the type IV vascular subgroup of Ehlers-Danlos syndrome, the arterial media is deficient, & patients are susceptible to dissections, pseudoaneurysms, & ruptures.*

Popliteal Artery Pseudoaneurysm: Color Doppler US

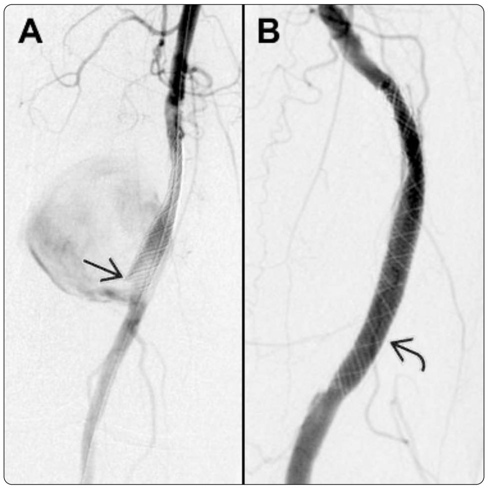


Popliteal Artery Pseudoaneurysm: Digital Subtraction Angiography

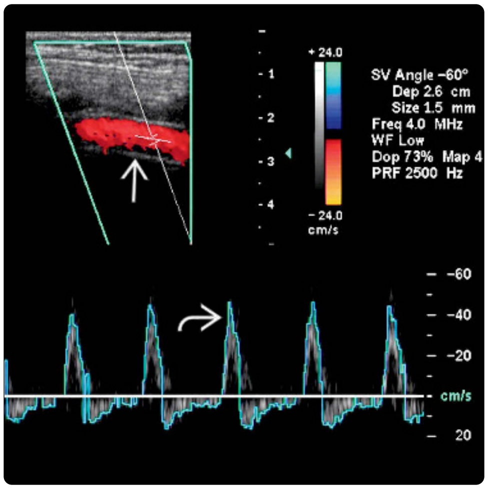


(Left) *Endovascular repair of the pseudoaneurysm was performed using covered stents. (A) The distal end of the initially placed stent → terminates in the neck of the pseudoaneurysm & does not extend sufficiently distally. (B) An overlapping stent ↷ was placed, completely excluding the pseudoaneurysm. The stents bridge the normal arterial segments on either side of the pseudoaneurysm.* **(Right)** *Color Doppler US after stenting shows a normal arterial waveform ↷ within the stents → & no pseudoaneurysm filling.*

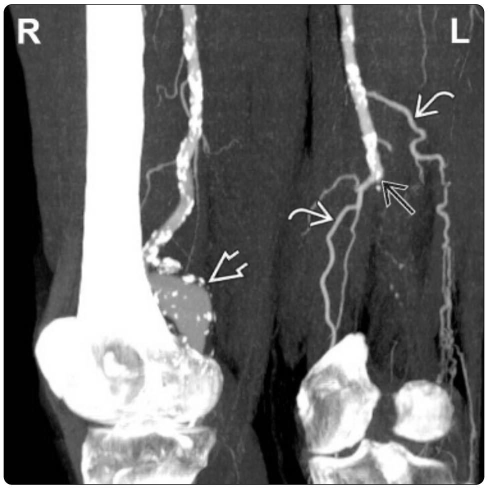
Popliteal Artery Pseudoaneurysm: Endovascular Exclusion



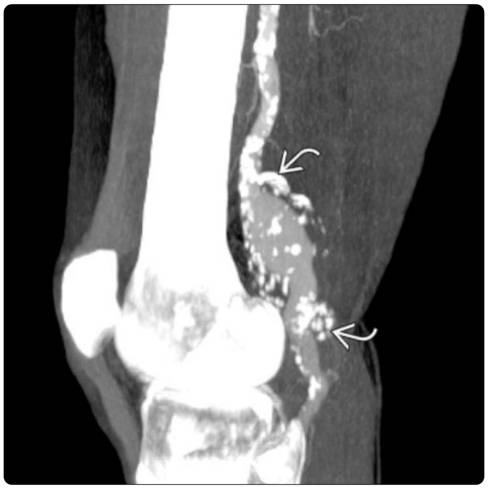
Popliteal Artery Pseudoaneurysm: US Following Exclusion



Popliteal Artery Aneurysm Exclusion: Evaluation With CTA Reconstruction

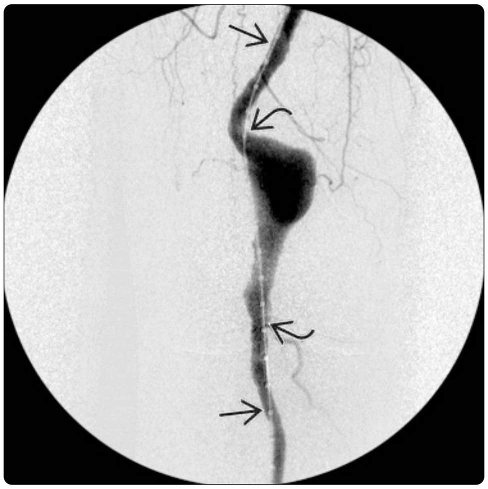


Popliteal Artery Aneurysm Exclusion: Evaluation With CTA Reconstruction

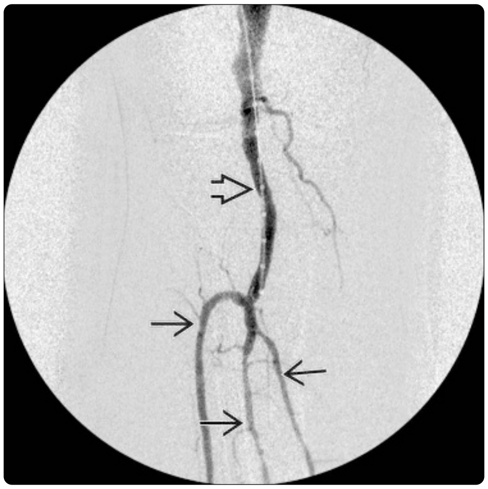


(Left) *CTA in a patient with left leg claudication shows a large right popliteal artery aneurysm* ⇨*. The left popliteal artery* → *is occluded due to a thrombosed popliteal artery aneurysm. Large collaterals* ↷ *extend distally & reconstitute the infrapopliteal runoff, explaining the lack of critical limb ischemia.* **(Right)** *Sagittal CTA shows the fusiform right popliteal artery aneurysm* ↷ *more clearly. The aneurysm diameter of 25 mm exceeds the minimal size criterion for intervention, thus warranting aneurysm repair or exclusion.*

Popliteal Artery Aneurysm Exclusion: Intraoperative DSA Evaluation

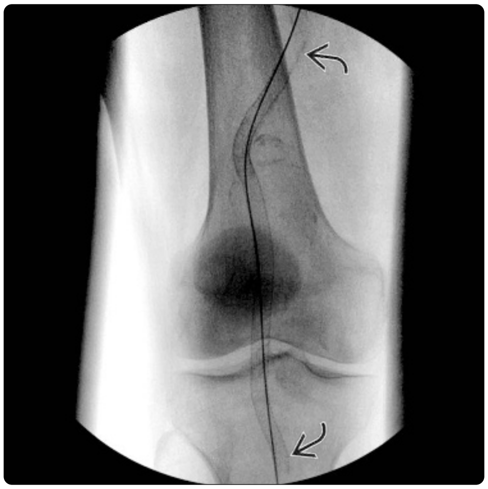


Popliteal Artery Aneurysm Exclusion: Intraoperative DSA Evaluation

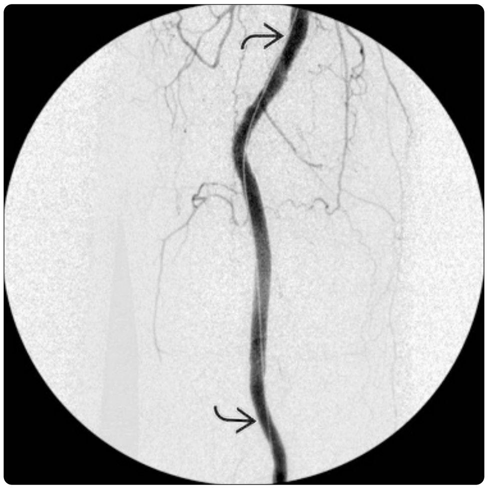


(Left) *A vascular sheath was introduced via antegrade common femoral artery access, & a calibrated catheter* → *was placed across the length of the aneurysm* ↷*. DSA via the access sheath delineates the aneurysm morphology. The catheter calibrations are used to determine the proper length endoprosthesis for aneurysm exclusion.* **(Right)** *DSA of the upper calf shows 3-vessel runoff* → *& a normal-caliber below-knee popliteal artery segment* ⇨ *that will serve as a satisfactory distal "landing zone" for the covered stent.*

Popliteal Artery Aneurysm Exclusion: Covered Stent Endoprosthesis

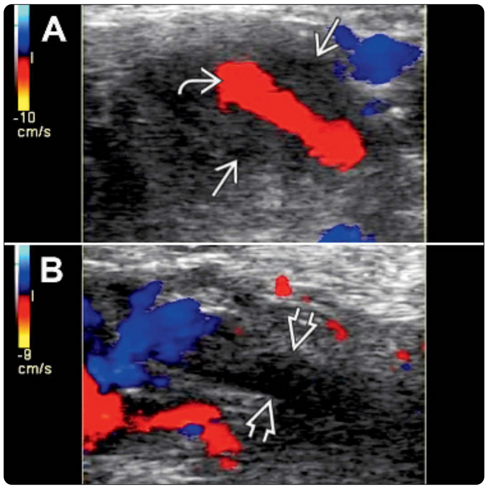


Popliteal Artery Aneurysm Exclusion: After Covered Stent Endoprosthesis

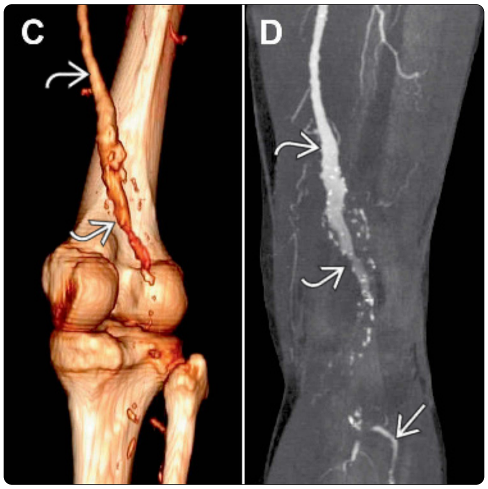


(Left) *A Viabahn covered stent* ↷ *was advanced over the guidewire & was positioned spanning the entire aneurysm. It is important that the proximal & distal ends attach within disease-free, normal-caliber arterial segments & that the guidewire remains indwelling during & after deployment.* **(Right)** *After covered stent placement, it may be necessary to gently angioplasty the proximal & distal attachments of the stent-graft to the native artery. DSA afterward shows a patent covered stent* ↷ *that excludes the aneurysm.*

Thrombosed Popliteal Artery Aneurysm: Color Doppler US Evaluation

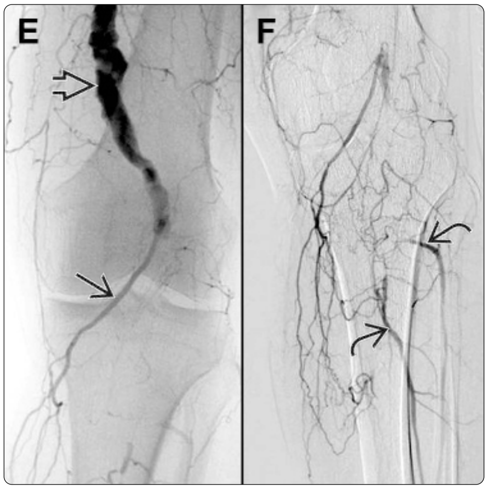


Thrombosed Popliteal Artery Aneurysm: Evaluation With CT Reconstruction

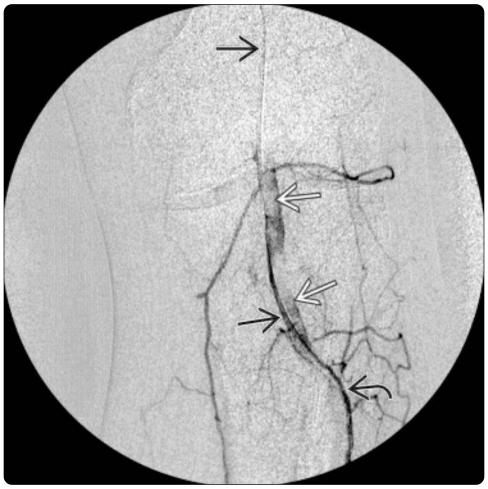


(Left) *A 63-year-old man presented with acute left leg ischemia without sensory loss or muscle weakness. Sagittal color Doppler US of (A) the suprapatellar segment of the popliteal artery shows a partially thrombosed aneurysm → with a patent central flow lumen ↪. (B) The infrapatellar aneurysm segment is thrombosed ⇨.* **(Right)** *(C) 3D reformation & (D) CTA MIP images confirm a fusiform left popliteal artery aneurysm ↪ that occludes near the knee joint. Discontinuous infrapopliteal runoff → can also be seen.*

Thrombosed Popliteal Artery Aneurysm: Intraoperative DSA Evaluation

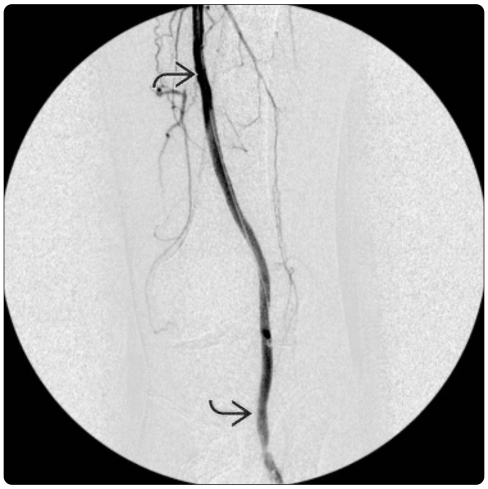


Thrombosed Popliteal Artery Aneurysm: Catheter-Directed Thrombolysis

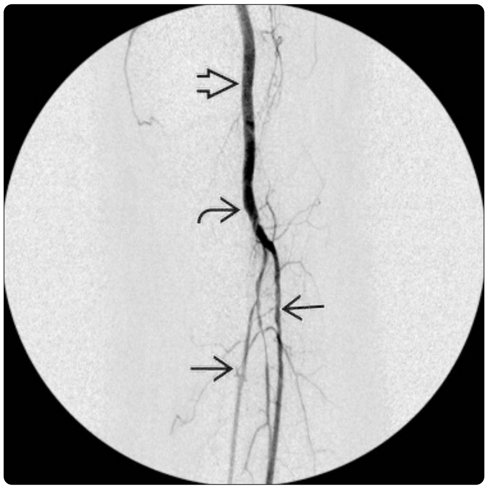


(Left) *The clinical status of the limb permitted catheter-directed thrombolysis of the thrombosed aneurysm with endovascular exclusion & revascularization. DSA shows that (E) the patent portion of the aneurysm ⇨ ends in a large collateral → that (F) reconstitutes the runoff arteries ↪.* **(Right)** *An infusion catheter was advanced through the thrombosed segment for continuous infusion of tPA. DSA shows that the catheter → extends through the distal popliteal artery thrombus → into the anterior tibial artery ↪.*

Thrombosed Popliteal Artery Aneurysm: After Covered Stent Endoprosthesis

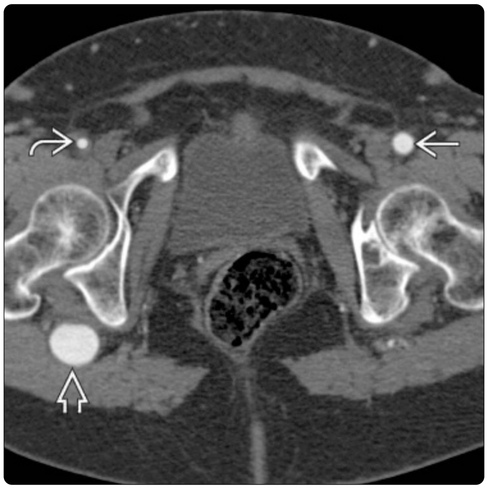


Thrombosed Popliteal Artery Aneurysm: After Covered Stent Endoprosthesis

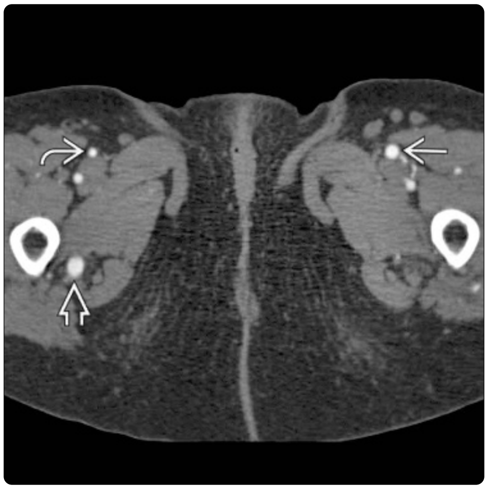


(Left) *After restoring patency to the thrombosed popliteal artery, a Viabahn covered stent ↪ was placed with the proximal attachment in the normal-caliber portion of the above-knee popliteal artery, as seen on this DSA. Distally, the endoprosthesis was extended into a normal-caliber arterial segment in the upper calf.* **(Right)** *DSA shows that the endoprosthesis ⇨ is patent, & the aneurysm is excluded, whereas the arterial runoff → to the lower leg is preserved. The stent attaches distally ↪ above the anterior tibial artery origin.*

Persistent Sciatic Artery: Axial CECT Evaluation

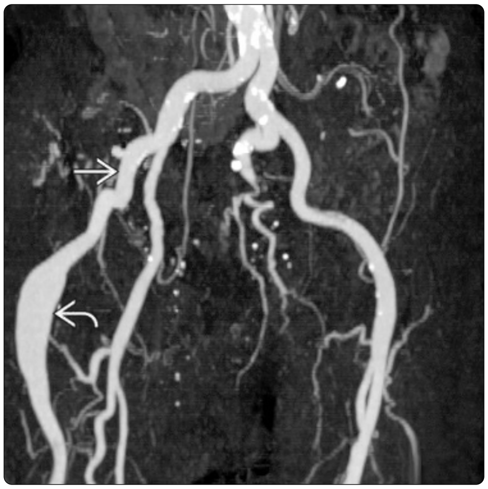


Persistent Sciatic Artery: Axial CECT Evaluation

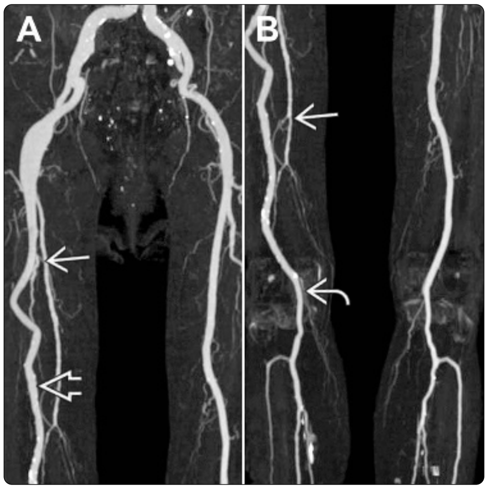


(Left) *CECT in a patient with a painful & pulsatile right buttock mass demonstrates an aneurysm ⇨ located posterolateral to the ischium. The right common femoral artery ↪ is diminutive in size relative to its counterpart on the left →.* **(Right)** *CECT at a more inferior level shows that the right SFA ↪ is also diminutive in caliber compared with the left SFA →. The aneurysmal artery has tapered ⇨ & courses in the posterior thigh adjacent to the sciatic nerve sheath. The findings are consistent with persistent sciatic artery.*

Persistent Sciatic Artery: CTA Reconstruction

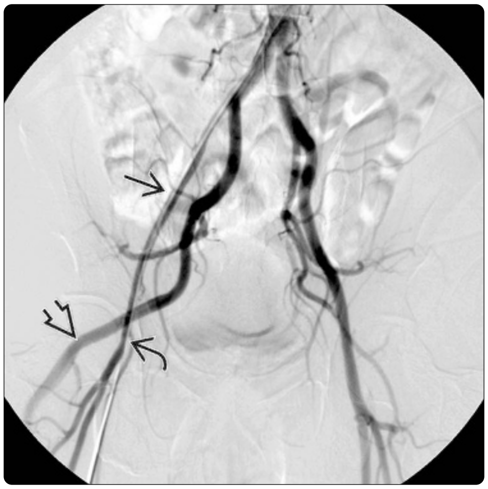


Persistent Sciatic Artery: CTA Reconstruction

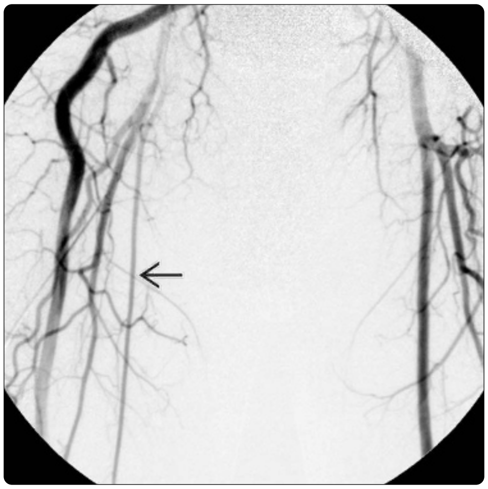


(Left) *Persistent sciatic artery is a congenital abnormality in which the embryonic lower extremity arterial supply persists. As this CTA shows, the internal iliac artery → continues as the sciatic artery ↪, which is aneurysmal & thus at risk for thrombosis or distal embolization.* **(Right)** *CTA at (A) thigh & (B) knee levels shows the complete form of persistent sciatic artery. The common & superficial femoral → arteries are atretic, while the sciatic artery ⇨ is the dominant arterial supply of the leg & continues as the popliteal artery ↪.*

Persistent Sciatic Artery: Angiographic Evaluation



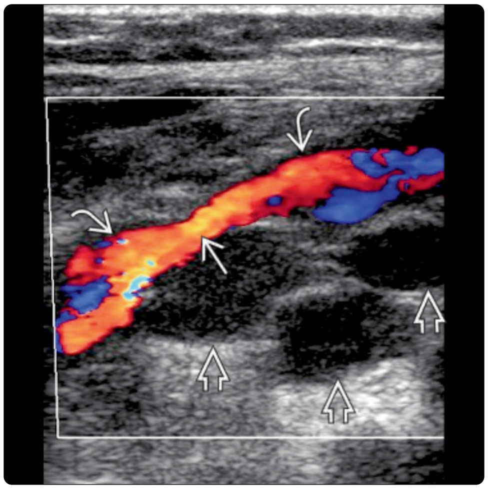
Persistent Sciatic Artery: Angiographic Evaluation



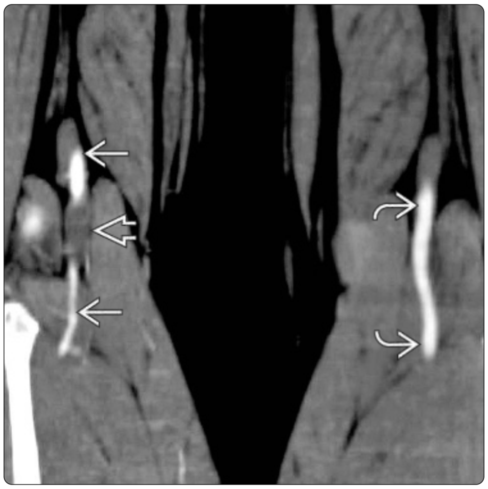
(Left) *DSA of the pelvis in a patient with this rare abnormality shows the hypoplastic right external iliac → & common femoral ↪ arteries with an enlarged but nonaneurysmal persistent sciatic artery ⇨.* **(Right)** *If the SFA → is hypoplastic, as in the complete form of this abnormality, & if exclusion of the persistent sciatic artery is clinically necessary, surgical bypass to the popliteal artery is required. Symptomatic persistent sciatic arteries have been treated via transcatheter embolization, endovascular repair, & surgical resection.*

(Left) *Color Doppler US in a patient with unilateral calf claudication shows multiple hypoechoic masses ⇨ in the popliteal fossa, adjacent to the popliteal artery ↪. The artery is compressed → by at least 1 of the masses.* **(Right)** *A coronal reconstruction CTA shows a normal-caliber left popliteal artery ↪. The right popliteal artery → is abnormal with a low-attenuation mass ⇨ surrounding the vessel within the popliteal fossa. This corresponds to the hypoechoic masses seen on US.*

Cystic Adventitial Disease: Color Doppler US

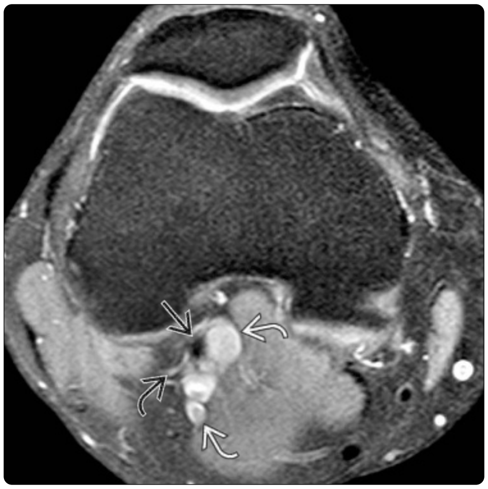


Cystic Adventitial Disease: Bilateral Lower Extremity CTA

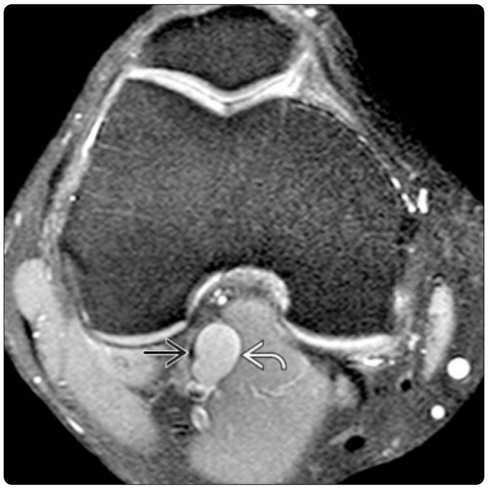


(Left) *Axial MR shows a normal flow void within the popliteal artery → but also demonstrates that the artery is compressed by round T2-bright masses ↪. The popliteal vein ↪ is also compressed & has a crescentic appearance. The findings are consistent with popliteal artery cystic adventitial disease.* **(Right)** *Axial PD FSE FS MR at a slightly lower level shows that the popliteal artery lumen → is reduced to a narrow slit due to compression by the very large cyst ↪ within the arterial adventitia.*

Cystic Adventitial Disease: Right Lower Extremity MRA

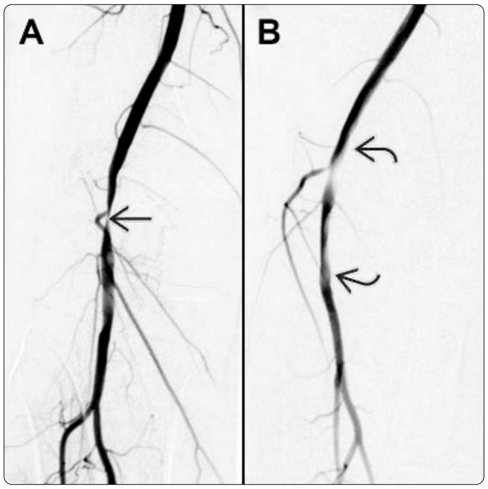


Cystic Adventitial Disease: Right Lower Extremity MRA

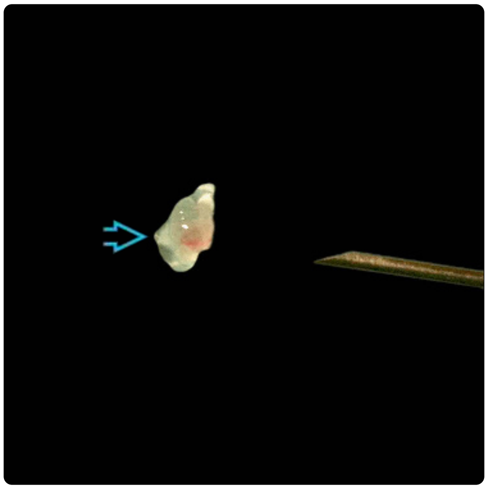


(Left) *(A) Frontal & (B) oblique DSAs show a severe popliteal artery stenosis → matching the slit-like lumen on MR. Cystic adventitial disease has a DSA appearance described as a spiral stenosis, as seen here. The undulating appearance of the artery ↪ is due to extrinsic compression by the cysts.* **(Right)** *US-guided cyst aspiration was successfully used for treatment. Removal of mucinous material ⇨ from the cysts excluded the artery from extrinsic compression, relieving symptoms. Usually treatment is via surgical cyst resection & vascular bypass.*

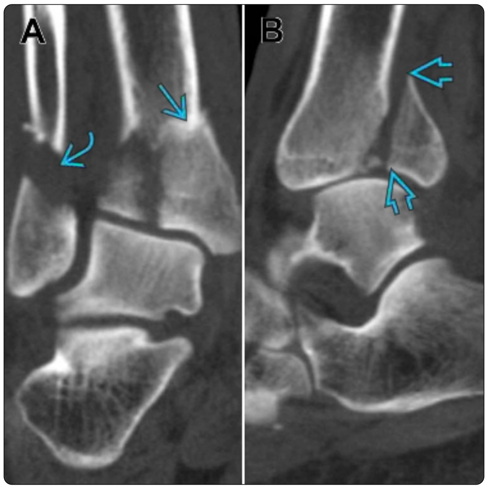
Cystic Adventitial Disease: Right Lower Extremity DSA



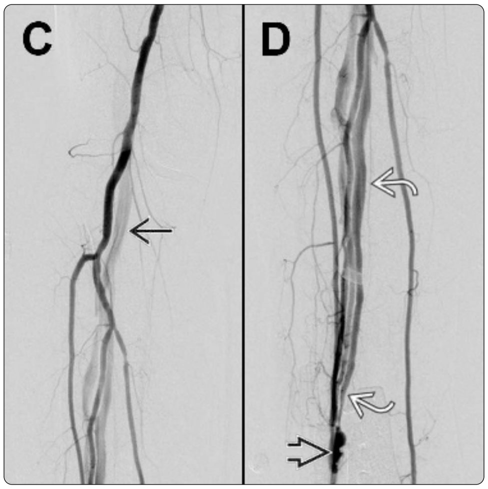
Cystic Adventitial Disease: Specimen From Cyst Aspiration



Traumatic Arteriovenous Fistula Caused by Trimalleolar Ankle Fracture

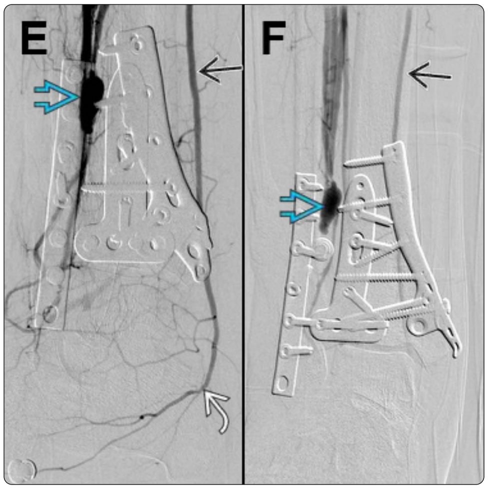


Traumatic Arteriovenous Fistula Caused by Trimalleolar Ankle Fracture: DSA

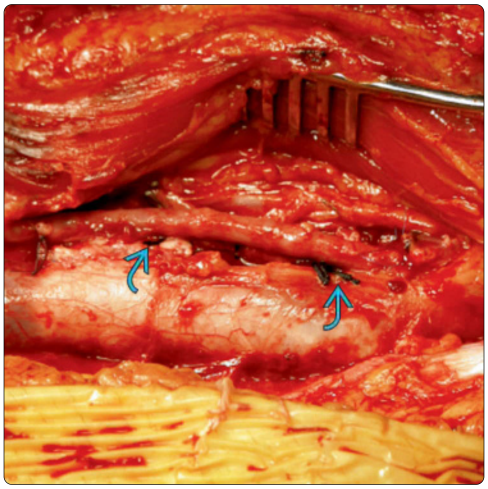


(Left) *A 28-year-old woman sustained right ankle trauma. (A) Coronal & (B) lateral reformations show fractures of the medial* ⇨ *& lateral* ↗ *malleoli & the posterior malleolar lip* ⇨ *of the tibial plafond. The patient underwent open reduction & internal fixation.* **(Right)** *Because of her complaint of persistent & severe foot pain, with pallor & coolness, she underwent DSA, which shows (C) early filling of the popliteal vein* ⇨ *& (D) of the calf veins* ➦ *as result of a posttraumatic arteriovenous (AV) fistula* ⇨ *at ankle level.*

Traumatic Arteriovenous Fistula Caused by Trimalleolar Ankle Fracture: DSA

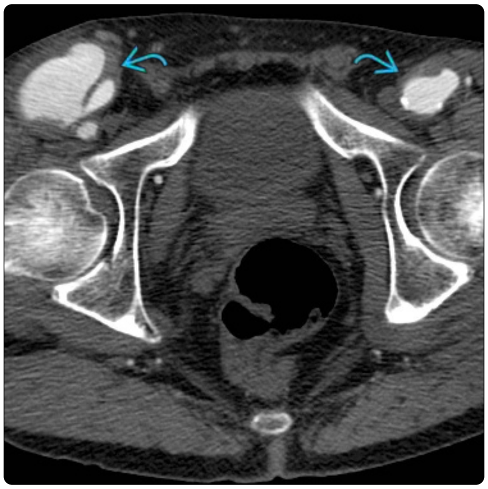


Traumatic Arteriovenous Fistula Caused by Trimalleolar Ankle Fracture: Surgery

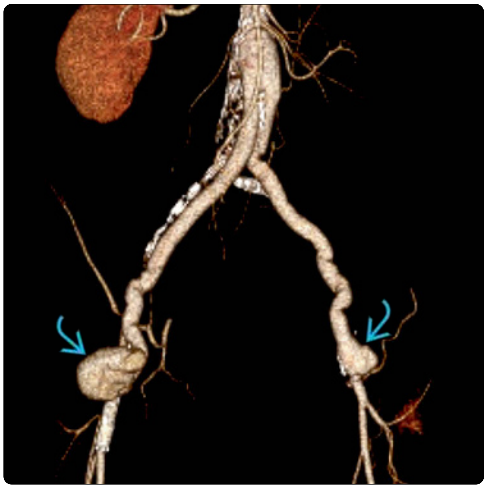


(Left) *(E) Oblique & (F) AP images at ankle & foot level again show the AV fistula* ⇨*. The posterior tibial artery* ⇨ *perfuses the plantar arch* ➦ *of the foot normally, but the dorsal arch does not fill, as a result of a steal phenomenon caused by the AV fistula.* **(Right)** *Because of the ischemic foot symptoms & poor perfusion of the dorsal arch, it was elected to surgically ligate* ↗ *& repair the AV fistula, as shown in the photograph, rather than to attempt embolization of the fistula or another endovascular intervention.*

Anastomotic Pseudoaneurysms Following Aortobifemoral Bypass Surgery



Anastomotic Pseudoaneurysms Following Aortobifemoral Bypass Surgery



(Left) *The choice of surgical or endovascular treatment must be individualized to the patient & should consider the specific anatomy & pathophysiologic process. This patient who presented with pulsatile bilateral groin masses several years after aortobifemoral bypass surgery was found by CT to have large anastomotic pseudoaneurysms* ↗*.* **(Right)** *The size, location, & etiology of the bilateral anastomotic pseudoaneurysms* ↗ *made open surgical repair a much more appropriate treatment option than an endovascular one.*

Chronic Total Occlusion Revascularization

KEY FACTS

TERMINOLOGY

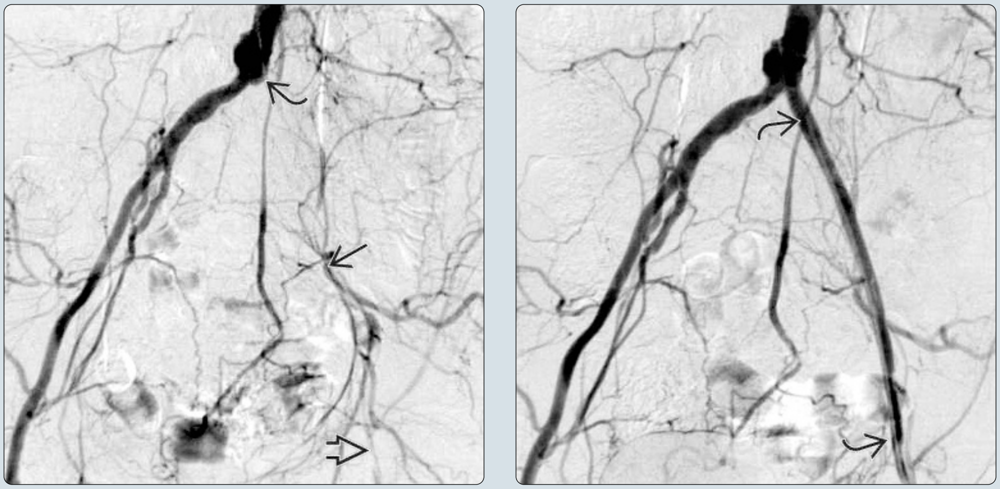
- **Chronic total occlusion (CTO)**: Complete arterial blockage (e.g., > 99%); usually due to atherosclerosis
    - Has fibrous cap; varying degrees of hard/soft plaque
- **Intraluminal recanalization**: Guidewire/catheter combination used to traverse CTO
- **Subintimal recanalization**: Intentional extraluminal passage of guidewire/catheter in subintimal space during attempted CTO revascularization
- **Subintimal recanalization with sharp re-entry**: Specialized re-entry catheter used to gain access into distal arterial segment after subintimal recanalization
- **Subintimal arterial flossing with antegrade-retrograde intervention (SAFARI) technique**: Retrograde puncture of reconstituted target artery after unsuccessful attempted antegrade recanalization

PROCEDURE

- Obtain vascular access; introduce sheath/guidewire
    - Position catheter proximal to target occlusion
- Use access sheath and catheter as coaxial system
    - Advance guidewire into proximal edge of CTO
- Advance guidewire/catheter until CTO crossed
    - May require subintimal recanalization
- Subintimal recanalization requires distal re-entry
    - May require re-entry device or SAFARI technique
- Proceed to angioplasty/stenting over guidewire

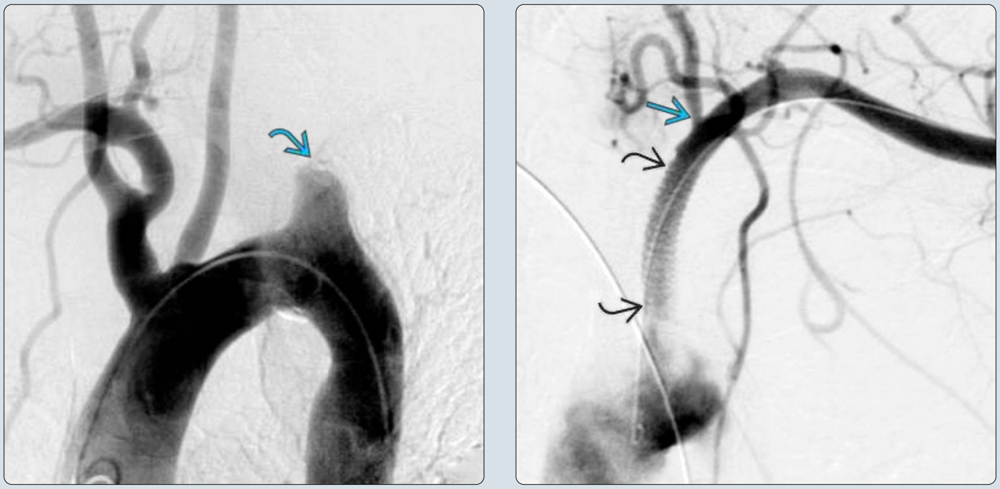
POST PROCEDURE

- Initiate antiplatelet therapy
    - Clopidogrel 75 mg daily (short duration vs. lifetime)
    - Aspirin 81 mg or 325 mg daily (lifetime)
- Clinically monitor patient for any suggestion of recurrence
- Risk factor modification
    - Control hyperlipidemia, hypertension, diabetes
- Technical success rate of procedure: 80-90%
- Clinical success rate at 1 year: 50-70%
    - Limb salvage rate: 80-90%


Left Common and External Iliac Artery CTO (Angiogram Prior to Revascularization)

Left Common and External Iliac Artery CTO (Angiogram After Revascularization)

(Left) *Pelvic DSA in a patient with claudication shows occlusion of the left common ↷ and external iliac arteries with collateral reconstitution of distal branches of the left internal iliac artery →. There is also faint opacification of a reconstituted left common femoral artery ⇨.* **(Right)** *DSA following recanalization of the left common and external iliac artery chronic total occlusion (CTO) shows an intravascular stent ↷ originating in the distal abdominal aorta and terminating above the inguinal ligament at the common femoral artery origin.*


Left Subclavian Artery Occlusion (Angiogram Prior to Revascularization)

Left Subclavian Artery Occlusion (Angiogram After Revascularization)

(Left) *Thoracic aortogram obtained in a patient with left arm claudication and episodes of syncope shows occlusion ↷ of the left subclavian artery distal to its origin from the aortic arch and proximal to the left vertebral artery origin. Delayed images showed left subclavian artery reconstitution via vertebral artery retrograde flow (subclavian steal).* **(Right)** *The CTO was recanalized using combined left brachial and right femoral arterial access, and a covered stent ↷ was placed, terminating proximal to the vertebral origin →.*

TERMINOLOGY

Definitions

- **Chronic total occlusion (CTO)**: Complete arterial blockage (e.g., > 99%); usually due to atherosclerosis
  - Typically present for > 3 months
    - Characterized by fibrous cap; varying degrees of hard and soft plaque
  - In peripheral artery disease (PAD), occlusion predominates over stenosis
    - Predominance due to limited collaterals
- **Chronic total venous occlusion**: Complete venous blockage; usually due to chronic thrombosis
  - Characterized by fibrosis; numerous collaterals
- **Trans-Atlantic Inter-Society Consensus II (TASC II)**: Comprehensive document for PAD management
  - Multiple recommendations in document
    - Risk factor modification
    - Evaluation strategies
    - Medical/surgical/endovascular management of
      - Intermittent claudication
      - Critical limb ischemia
      - Acute limb ischemia
  - Lesions categorized with recommendations for endovascular vs. surgical treatment based on
    - Lesion location (e.g., aortoiliac/femoropopliteal)
    - Lesion type (stenosis vs. occlusion)
    - Lesion length/disease severity in runoff arteries
  - **TASC II categories**
    - **Type A**: Endovascular procedures recommended
      - Should be 1st-line treatment
    - **Type B**: Endovascular procedures recommended
      - Unless surgery required for other lesions located in same anatomic area
    - **Type C**: Open revascularization recommended
      - Endovascular procedures recommended only if potential for poor healing after open surgery
    - **Type D**: Endovascular procedures not recommended as 1st-line treatment
  - TASC III Consensus preparations currently ongoing

CTO Revascularization Techniques

- **Intraluminal recanalization**: Guidewire and catheter combination used to traverse chronically thrombosed/plaque-filled arterial lumen
  - Must initially penetrate proximal edge of CTO
  - Guidewire/catheter then used to negotiate entire length of CTO while remaining intraluminal
    - Must enter reconstituted patent lumen below CTO
- **Subintimal recanalization**: Intentional extraluminal passage of guidewire/catheter in subintimal space during attempted CTO revascularization
  - Subintimal space is actually potential space
    - Path of least resistance in CTO compared to chronically occluded true lumen vessel
      - Allows fairly easy guidewire/catheter passage
  - Requires guidewire/catheter re-entry into reconstituted distal arterial segment
    - Failure to re-enter true lumen after subintimally crossing CTO is primary limitation to success
    - Failure to achieve re-entry until quite distal to point of arterial reconstitution may put additional branch points/collaterals at risk
  - If subintimal angioplasty/stenting extends excessively beyond occluded segment
    - May put potential "no-stent zones" (e.g., common femoral/popliteal arteries) at risk
- **Subintimal recanalization with sharp re-entry**: Specialized re-entry catheter used to gain access into distal arterial segment after subintimal recanalization
  - Standard subintimal recanalization performed
  - Catheter fails to re-enter distal arterial segment
    - Catheter removed leaving guidewire subintimal
  - Re-entry catheter advanced over guidewire
  - Small directionally controlled hollow needle near catheter tip used to pierce intima into true lumen
    - Microwire introduced via needle into true lumen
  - Device removed, leaving microwire in place to allow catheter placement across CTO
- **Subintimal arterial flossing with antegrade-retrograde intervention (SAFARI) technique**: Retrograde puncture of reconstituted target artery after unsuccessful attempted antegrade recanalization
  - Retrograde subintimal recanalization then performed from distal puncture access site
    - Guidewire/catheter passed retrograde though CTO
    - Guidewire must enter subintimal space/vessel lumen where antegrade catheter located
  - Retrograde guidewire snared via antegrade catheter
    - Snared guidewire withdrawn via antegrade sheath
      - Creates "flossing" guidewire permitting placement of catheter/PTA balloon across CTO

PREPROCEDURE

Indications

- General
  - Symptomatic CTO
    - Prefer TASC A/B/C lesions
- **Subintimal recanalization**
  - Failed attempts at intraluminal recanalization
  - Large collateral vessel proximal to CTO
    - Persistent guidewire entry into collateral during attempt at crossing occlusion
  - Heavily calcified lesions preventing intraluminal guidewire/catheter passage
- **Sharp re-entry device**
  - Failure to gain distal re-entry with subintimal recanalization
- **SAFARI technique**
  - Failed attempts at antegrade recanalization

Contraindications

- TASC D lesion (relative contraindication)
  - Surgical bypass recommended treatment
    - Must be suitable surgical candidate
  - Increasing evidence that many TASC D lesions can be successfully treated endovascularly
- Inadequate or absent runoff distal to occlusion

Getting Started

- Things to check

  - Clinical history and physical examination
    - Appropriate procedure indications
    - Comprehensive vascular evaluation
      - Documentation of peripheral pulses
    - Review prior endovascular/surgical interventions
      - May influence choice of optimal access
    - Current medications
      - Any anticoagulants, antiplatelet agents, oral hypoglycemic agents
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - Complete blood count (CBC)
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ratio ≤ 1.5
      - Normal prothrombin time, partial thromboplastin time
  - Limit oral intake: Npo for 8° prior to procedure
    - Necessary for moderate sedation
    - Take any oral medications with sip of water
- Medications
  - Heparin
    - Usually administered intraprocedurally
    - May occasionally be continued post procedure
      - Small vessels, sluggish flow, poor distal runoff
  - Vasodilator (e.g., nitroglycerin)
    - Typical bolus dose of 100 μg of nitroglycerin
    - Prevents/treats catheter-induced vasospasm
  - Clopidogrel
    - May electively give loading dose before procedure
      - 300 mg minimum loading dose
    - Continue maintenance dose post procedure
      - 75-mg daily dose for 4-6 weeks minimum
- Equipment list
  - Access sheaths: Ensure adequate diameter for optimal visualization/device delivery
    - 5- to 8-Fr vascular access sheath
    - Crossover access sheath (for contralateral access)
      - e.g., Ansel, Balkin sheaths
  - Atherectomy devices
    - May be used to debulk atherosclerotic lesion after crossing CTO
    - May be combined with other treatment modalities
      - Drug coated balloon angioplasty
  - Catheters
    - Diagnostic catheter
      - Flush (e.g., pigtail) or straight catheter initially
    - Selective catheter
      - May be used to direct guidewire across lesion
      - Hydrophilic straight/angled catheter often useful in crossing CTO
    - Specialty catheters/devices for crossing CTO
      - Crosser CTO recanalization catheter (CR Bard; Murray Hill, NJ)
      - Quick-Cross support catheter (Spectranetics; Colorado Springs, CO)
      - Wildcat catheter (Avinger; Redwood City, CA)
      - FRONTRUNNER XP CTO catheter (Cordis; Miami Lakes, FL)
    - Angioplasty (PTA) balloon catheter
      - Balloon diameter, length based on target lesion
      - High-pressure vs. low-pressure balloon
      - Insufflator for balloon inflation
    - Drug-coated angioplasty balloon catheters
      - Various proprietary options
      - Lower incidence of intimal hyperplasia and lesion recurrence
  - Guidewires
    - Initial "starting" 0.035" guidewire
    - Angled or straight-tipped hydrophilic guidewire
      - Often beneficial for crossing lesion
    - Stiff guidewire
      - e.g., Amplatz, Lunderquist, Rosen
      - Stability when advancing devices across lesion
      - May need exchange length for distal lesions
    - Microwire (0.014-0.018")
      - For use with coaxial microcatheter
      - For use with re-entry device
  - Re-entry catheters/devices
    - Outback re-entry catheter (Cordis)
      - Radiopaque markers allow fluoroscopic device orientation for directing curved re-entry needle
    - Pioneer (Medtronic; Minneapolis, MN)
      - Equipped with intravascular US probe to identify true lumen for curved re-entry needle
  - Stents
    - Various proprietary options
    - Drug-eluting stents increasingly used
      - Lower incidence of in-stent stenosis caused by neointimal hyperplasia

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Ipsilateral retrograde approach for aortoiliac lesions
    - May require bilateral common femoral artery access, particularly if "kissing" stents needed
  - Ipsilateral antegrade approach or contralateral crossover approach for infrainguinal lesions

Equipment Preparation

- Flush catheters/sheaths with heparinized saline
- Immerse hydrophilic guidewires in heparinized saline

Procedure Steps

- **Intraluminal recanalization**
  - Sterilely prepare/drape intended access site
  - Obtain vascular access; introduce guidewire
    - May use fluoroscopic or US guidance
  - Introduce vascular access sheath over guidewire
  - Introduce appropriate diagnostic catheter via sheath
    - Obtain diagnostic DSA; evaluate target lesion
  - Exchange for selective catheter if necessary
    - Selectively catheterize target artery
    - Position catheter proximal to target occlusion
  - Use access sheath and catheter as coaxial system

    - Allows injection through sheath around inner catheter; localizes lesion during recanalization
    - Provides stability and rigidity to catheter when attempting to cross CTO
    - Allows device delivery during recanalization (e.g., PTA balloon, stent, atherectomy device)
  - Place selective catheter coaxially through sheath
    - Administer heparin bolus prior to crossing lesion
  - Position selective catheter tip at leading edge of CTO
  - Choose guidewire/catheter shapes based on
    - Need to direct recanalization centrally vs. away from calcium or adjacent side branch
  - Introduce hydrophilic guidewire via catheter
    - Keep catheter tip abutting cap of CTO
  - Advance guidewire into proximal edge of CTO
    - Must penetrate cap of occlusion; may require firm pressure to "break" cap with guidewire
      - Specialty crossing device (e.g., Crosser, FRONTRUNNER) may help penetrate/"break" cap
  - After penetrating proximal cap with guidewire, track hydrophilic catheter into occlusion
    - Gives guidewire support during CTO traversal
  - Continue to advance guidewire through CTO
    - Guidewire may form loop at tip while advancing
      - Try to maintain narrow loop width (~ width of target artery)
    - If wide loop occurs, advance catheter to loop apex
      - Withdraw guidewire into catheter; readvance guidewire to form new smaller loop
    - Can adjust trajectory within occluded segment using directional catheter/guidewire
  - Alternative guidewire/catheter technique
    - Use hydrophilic catheter with tight loop of Rosen guidewire immediately abutting catheter tip
      - Advance catheter/guidewire together as unit
    - Catheter provides support for Rosen; configuration avoids subintimal guidewire passage
      - Advancing round "J" interface of Rosen against plaque keeps guidewire/catheter intraluminal
  - Continue guidewire/catheter passage until CTO completely crossed
    - Must reach distal patent lumen with catheter
      - Confirm intraluminal position with DSA
  - Proceed to angioplasty/stenting over guidewire
- **Subintimal recanalization**
  - Same initial access and sheath/catheter/guidewire placement as for intraluminal recanalization
    - Use straight/angled hydrophilic guidewire and straight/angled hydrophilic catheter
  - Direct guidewire tip toward arterial wall
    - Try to avoid entering any large collaterals
  - Advance guidewire/catheter combination into CTO
    - When in subintimal space, should encounter minimal resistance while advancing
  - While advancing, manipulate hydrophilic guidewire tip into loop configuration
    - Advance catheter with guidewire loop protruding
  - Try to maintain relatively narrow loop width
    - Wide loop denotes patulous subintimal dissection
      - Significantly impairs successful distal re-entry
  - Continue to advance catheter/guidewire combination to level of distal reconstitution
    - Distal re-entry should be beyond CTO but as close as possible to reconstitution point
  - May need to straighten loop from guidewire tip; advance straightened guidewire into true lumen
    - Guidewire should move freely in true lumen
  - Advance catheter over guidewire into lumen
    - Confirm intraluminal position with DSA
  - Proceed to angioplasty/stenting over guidewire
- **Subintimal recanalization with sharp re-entry**
  - Procedure identical to subintimal recanalization except unable to achieve distal re-entry
    - Specialized catheter used to gain distal re-entry
      - Required in 10-15% of subintimal recanalizations in reported series
  - After unsuccessful attempts at re-entry into distal patent lumen from subintimal space
    - Leave guidewire indwelling; remove catheter
      - Guidewire tip should be just beyond distal reconstitution point
  - Introduce re-entry catheter over guidewire
    - Advance catheter to level of patent distal lumen
  - Orient re-entry catheter toward patent distal lumen
    - Use fluoroscopic (Outback) or US (Pioneer) orientation to identify patent lumen
  - Advance sharp curved re-entry needle across intima into patent distal lumen
    - Pass microwire through device and distal curved needle into distal patent true lumen
      - Retract curved needle; withdraw re-entry catheter leaving guidewire indwelling
  - Advance catheter over microwire across CTO into distal patent true lumen
    - May use rapid-exchange system to perform angioplasty of CTO
    - May exchange for stiff guidewire
      - Proceed to angioplasty/stenting over guidewire
- **SAFARI technique**
  - Procedure identical to subintimal recanalization except unable to achieve distal re-entry
    - Retrograde "docking" technique for recanalization
  - After unsuccessful attempts at distal re-entry
    - Leave catheter from antegrade approach indwelling subintimal space
  - Perform direct retrograde puncture of distal lumen
    - Use US or fluoroscopic guidance
  - Gain intraluminal access, place sheath or catheter into patent reconstituted distal lumen
    - Confirm intraluminal position with DSA
  - Use catheter/guidewire combination; perform retrograde intraluminal/subintimal recanalization
    - Continue retrograde recanalization until indwelling antegrade catheter is met
  - Introduce snare via antegrade catheter
    - Ensnare retrograde guidewire/catheter
      - Withdraw retrograde guidewire through antegrade sheath to create "flossing" guidewire
  - Place catheter over guidewire exiting antegrade sheath; advance across CTO into distal lumen

    - After catheter is across CTO from antegrade access, can remove retrograde catheter/sheath
  - Use antegrade access for subsequent interventions
    - Proceed to angioplasty/stenting over guidewire
    - Should not use retrograde access for intervention
      - Avoids damage to smaller caliber distal vessel

Alternative Procedures/Therapies

- Surgical
  - Surgical revascularization
    - Surgical bypass
    - Arterial endarterectomy
- Other
  - Medical management/exercise regimen (claudicants)
    - Can achieve satisfactory outcomes with dedicated supervised exercise regimen; unfortunately, no reimbursement for this strategy currently

POST PROCEDURE

Things to Do

- Initiate antiplatelet therapy
  - Clopidogrel 75 mg daily (short duration vs. lifetime)
  - Aspirin 81 mg or 325 mg daily (lifetime)
- Clinically monitor patient for any suggestion of recurrence
  - Obtain new baseline noninvasive imaging evaluation after successful revascularization
  - May consider following with periodic noninvasive imaging surveillance
- Risk factor modification
  - Hyperlipidemia
    - Patient should be on statin
  - Hypertension
    - Maintain optimal blood pressure control
  - Tobacco use
    - Strongly discourage tobacco use if patient is smoker
    - Refer patient to smoking cessation program
  - Diabetes
    - Maintain optimal glycemic control

OUTCOMES

Complications

- Most feared complication(s)
  - Distal embolization or in situ thrombosis
    - May be accompanied by loss of runoff vasculature
    - Can result in emergency open surgery
- Immediate/periprocedural complication(s)
  - Access site complications
    - Hematoma, pseudoaneurysm
    - Iatrogenic arteriovenous fistula formation
      - Antegrade access site (all techniques)
      - Retrograde access site (SAFARI technique)
  - Occlusion of collateral vessels
  - Vessel perforation with bleeding
    - May respond to prolonged balloon inflation
    - May require covered stent for treatment
- Delayed complication(s)
  - Contrast-induced nephropathy
  - Stenosis or thrombosis of recanalized native artery following drug-coated balloon angioplasty
    - May require repeat angioplasty for stenosis (primary assisted patency)
    - May require repeat recanalization and placement of intravascular stent for reocclusion (secondary patency)
  - Stent occlusion/thrombosis
    - Various causes
      - Intimal hyperplasia causing in-stent stenosis; may progress to occlusion; drug-coated balloon angioplasty useful for treating in-stent stenosis
      - Mechanical failure of implanted stent, usually due to fractured stent
      - Progression of PAD in outflow vessels distal to implanted stent

Expected Outcomes

- **Intraluminal recanalization**
  - Not uniformly successful; may require conversion to subintimal recanalization
  - Difficult to know if guidewire and catheter remained intraluminal through entire CTO length
- **Subintimal recanalization**
  - Technical success rate: 80-90%
  - Clinical success rate at 1 year: 50-70%
    - Primary patency rate: 50%
    - Limb salvage rate: 80-90%

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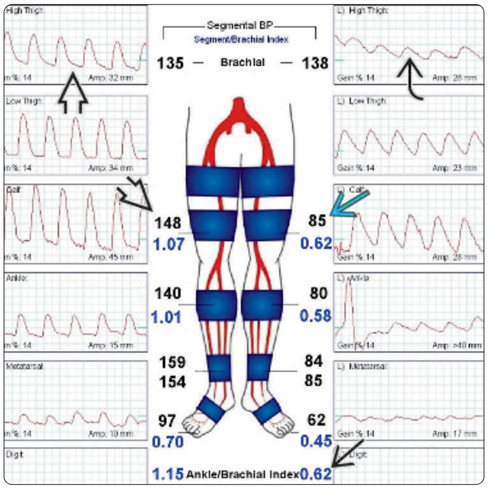
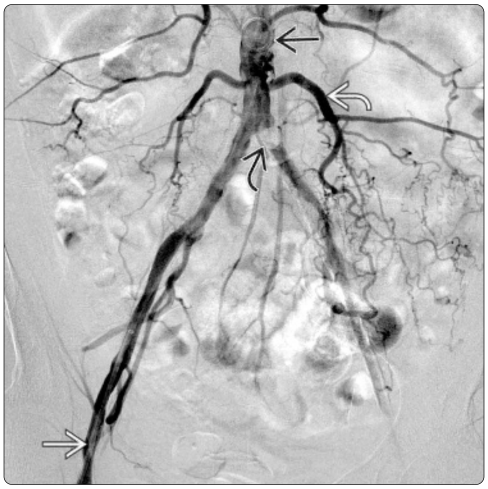
Left Common Iliac Artery CTO: Initial Noninvasive Evaluation

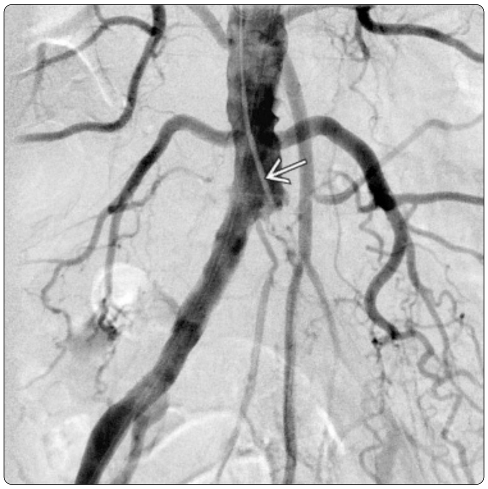


Left Common Iliac Artery CTO: Initial Diagnostic Pelvic DSA

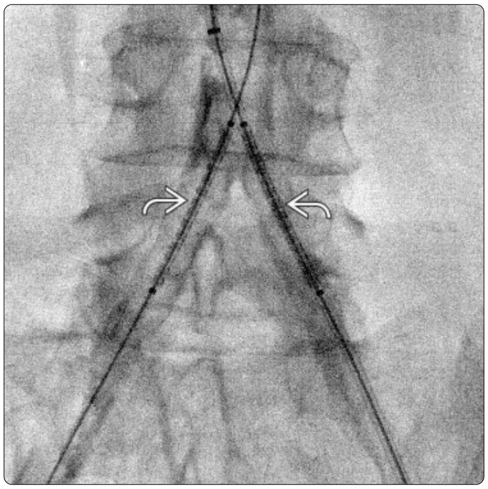


(Left) *Arterial noninvasive study in a patient with left thigh and buttock claudication shows diminished left-sided segmental limb pressures ⇨ and pulse volumes ⇨ at all levels, relative to those on the right ⇨, and an abnormal left ankle-brachial index of 0.62 ⇨. The findings indicate a pelvic arterial inflow lesion.* **(Right)** *Pelvic DSA via a right femoral arterial access ➡, with a pigtail catheter ⇨ in the distal aorta, shows a short segmental left common iliac artery occlusion ↪ and large lumbar artery collaterals on the left ⤻.*

Left Common Iliac Artery CTO: Retrograde Intraluminal Recanalization

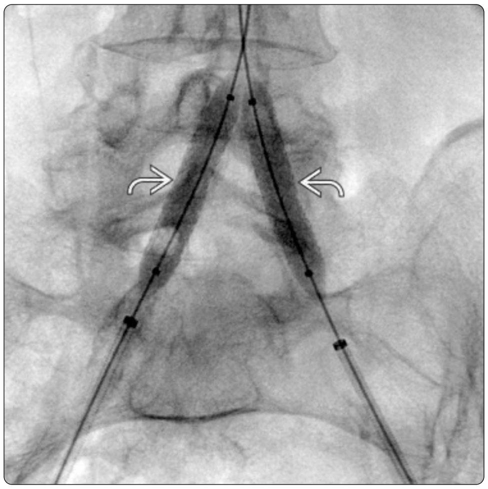


Left Common Iliac Artery CTO: "Kissing" Balloon-Mounted Stents

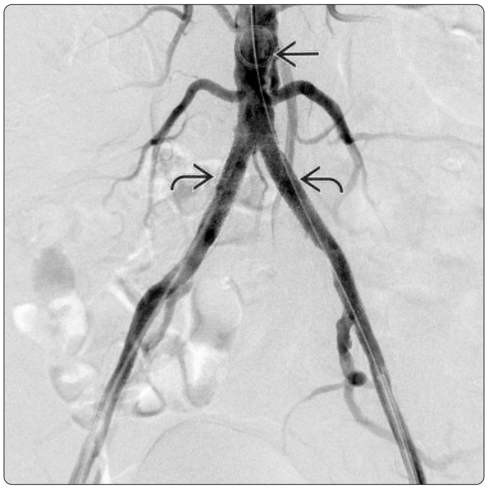


(Left) *A femoral access sheath was placed on the left. A straight catheter was placed over a hydrophilic guidewire, and this combination was advanced retrograde to the occlusion level. The guidewire was advanced across the CTO, and the hydrophilic catheter ➡ then followed over the guidewire into the distal aorta.* **(Right)** *Common iliac artery origin stenoses or occlusions require bilateral "kissing" stents. The right-sided pigtail catheter was removed over a guidewire, and balloon-mounted stents ⤻ were introduced bilaterally.*

Left Common Iliac Artery CTO: Simultaneous Stent Deployment



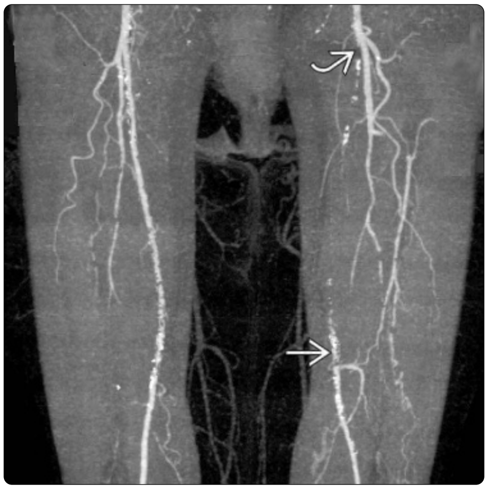
Left Common Iliac Artery CTO: Posttreatment Pelvic DSA



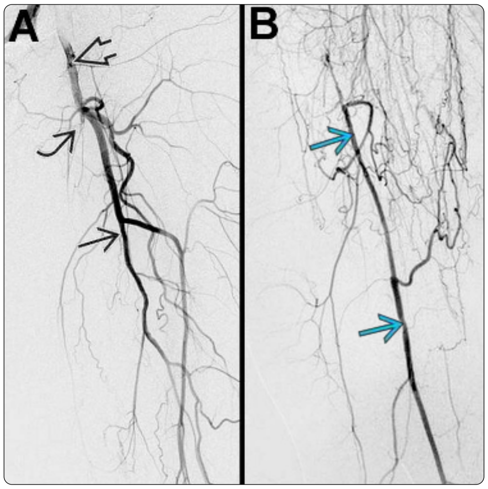
(Left) *The balloon-mounted stents were positioned so that they both extended slightly into the distal aorta, ensuring that the left common iliac occlusion would be adequately bridged by the stent. The balloons ⤻ were simultaneously inflated, thereby deploying both stents.* **(Right)** *After removing the balloon catheters over guidewires, the pigtail catheter ⇨ was reintroduced and placed in the distal aorta. Posttreatment DSA shows that both stents ↪ are in good position and the left common iliac artery is patent.*

(Left) *Coronal CTA obtained in a patient with left lower extremity rest pain shows occlusion of the superficial femoral artery (SFA) ➡ at or very near the vessel origin. There is reconstitution of the above-knee popliteal artery ➡ via profunda femoral artery collaterals.* **(Right)** *Left lower extremity DSA shows (A) the common ➡ and profunda femoral ➡ arteries are patent. There is a nipple-like projection ➡ remaining at the origin of the occluded SFA. (B) As seen on CTA, the above-knee segment of the popliteal artery ➡ is reconstituted.*

Antegrade SFA Recanalization: Initial CTA Reformation

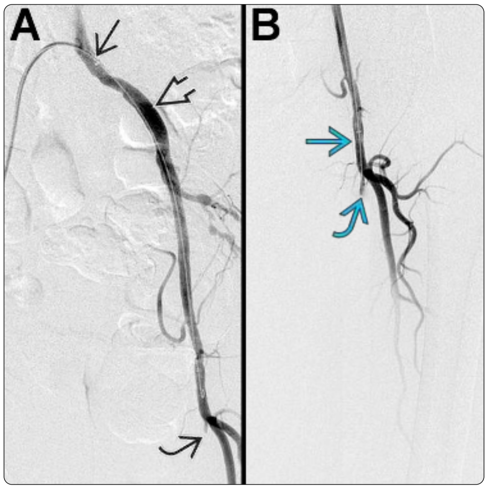


Antegrade SFA Recanalization: Left Femoropopliteal DSA

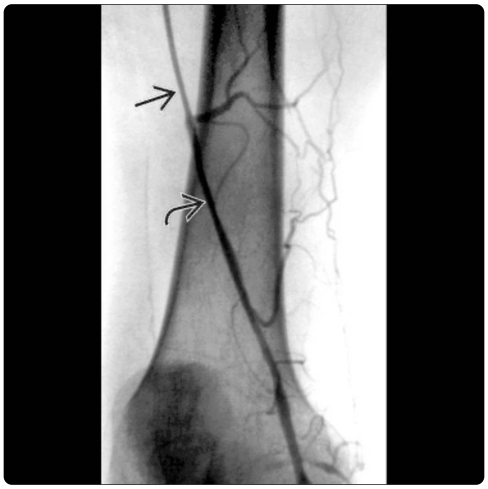


(Left) *(A) An Ansel sheath ➡ was placed over the aortic bifurcation into the left common iliac artery ➡. This allows contrast injection around an inner catheter during recanalization, as in this DSA showing the residual nipple ➡ of the occluded SFA. (B) The sheath has been placed in the common femoral artery ➡, and a guidewire and catheter have engaged the CTO ➡.* **(Right)** *After engaging the fibrous cap, the guidewire and catheter ➡ were advanced until re-entry into the reconstituted lumen ➡, as shown by DSA.*

Antegrade SFA Recanalization: Catheter and Guidewire Placement

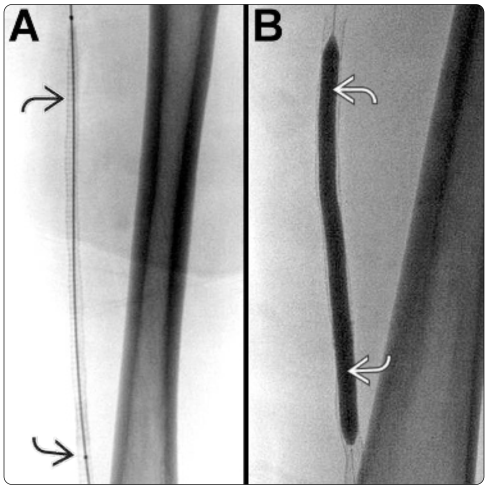


Antegrade SFA Recanalization: Catheter and Guidewire Across CTO

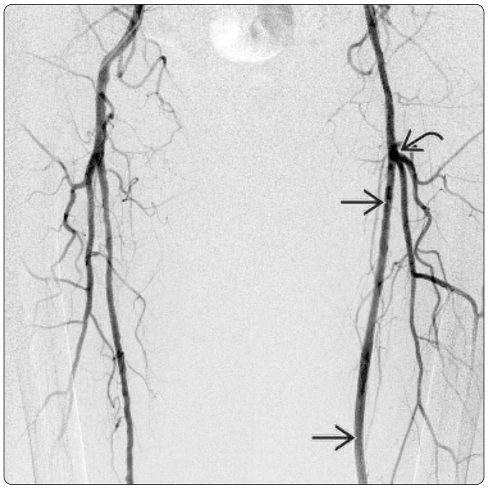


(Left) *The guidewire was left indwelling, the catheter was removed, and angioplasty was performed with a suboptimal result. (A) Afterward, a covered stent ➡ was placed in the recanalized segment. (B) The stent was distended to the 6-mm target diameter using a PTA balloon ➡.* **(Right)** *DSA after CTO revascularization shows that left SFA patency ➡ has been restored via covered stent placement. The stent does not extend to the SFA origin so as to avoid encroachment on the profunda femoral artery origin ➡ and possible occlusion.*

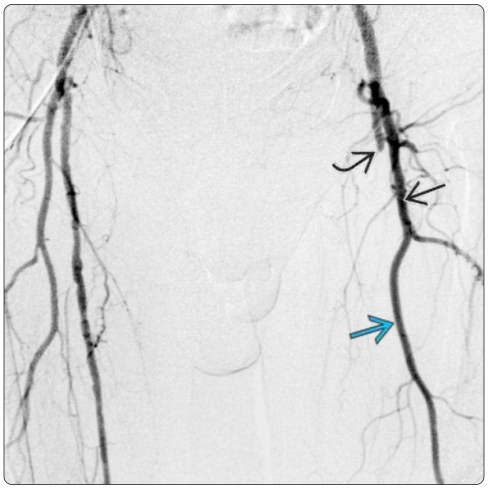
Antegrade SFA Recanalization: Self-Expanding Stent Placement



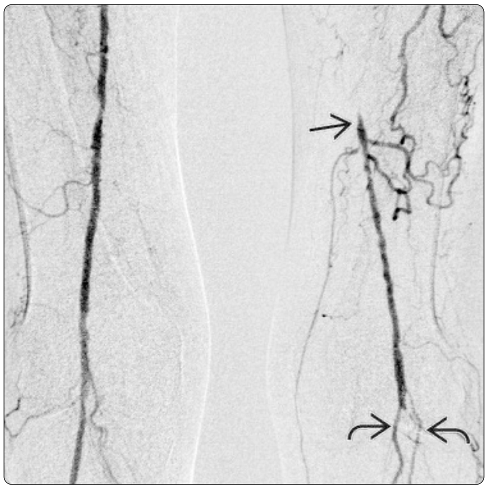
Antegrade SFA Recanalization: Posttreatment Runoff DSA



SAFARI Technique for CTO: Initial Femoropopliteal DSA

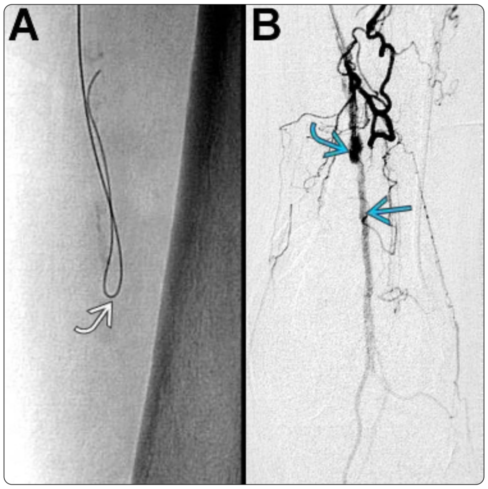


SAFARI Technique for CTO: Initial Femoropopliteal DSA

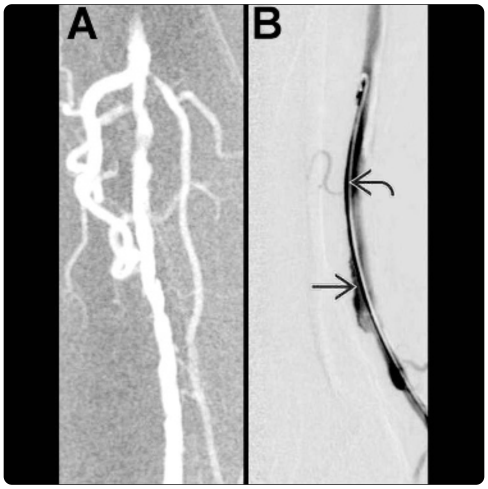


(Left) *DSA of the thighs in a patient with left leg ischemia shows occlusion of the left superficial femoral artery ↪ 3 cm beyond its origin. The left profunda femoral artery → and its branches are enlarged → compared to the right, as they provide significant collateral flow.* **(Right)** *DSA of the distal thighs and knees shows a reconstituted above-knee segment of the left popliteal artery → at the adductor hiatus via profunda collaterals. The popliteal artery terminates in collaterals ↪ at the knee joint.*

SAFARI Technique for CTO: Attempted Subintimal Recanalization

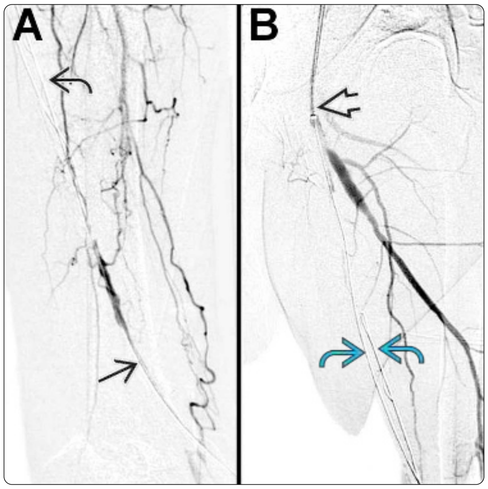


SAFARI Technique for CTO: Retrograde Popliteal Puncture

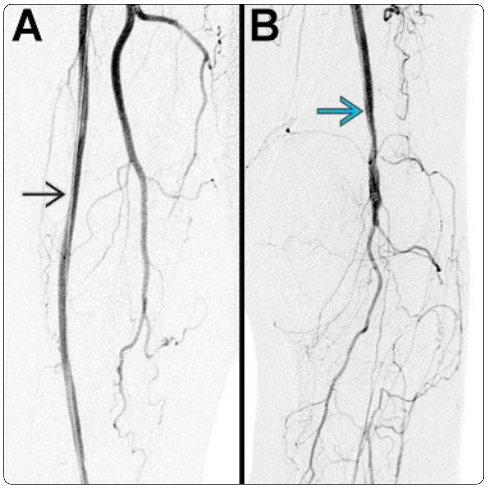


(Left) *(A) Subintimal SFA recanalization was attempted with successful subintimal guidewire passage. A loop ➦ may form at the guidewire tip while advancing. One should maintain a narrow loop to avoid an expanding subintimal dissection. (B) At the level of popliteal reconstitution, re-entry into the patent lumen → was unsuccessful. A widened dissection channel ↪ is evident.* **(Right)** *Using US and (A) roadmap fluoroscopy guidance, (B) a retrograde popliteal artery → puncture was performed, and a guidewire ↪ was placed.*

SAFARI Technique for CTO: Subintimal Arterial Flossing



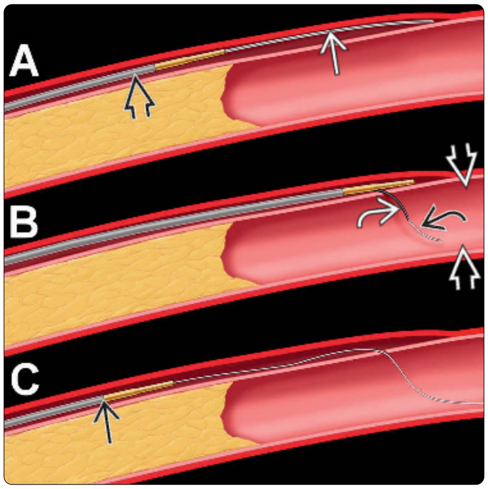
SAFARI Technique for CTO: Completion Femoropopliteal DSA



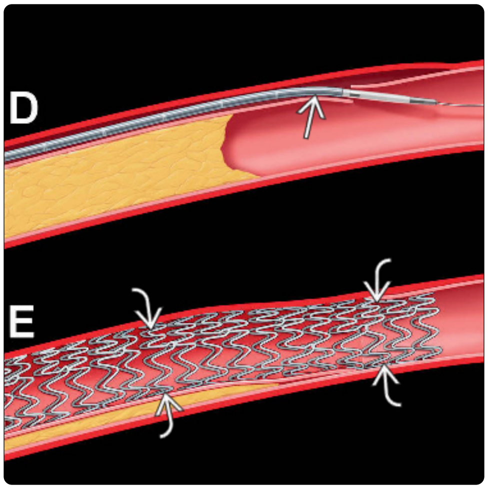
(Left) *(A) After gaining popliteal access, a sheath was placed, through which a guidewire and catheter → were used for retrograde recanalization to the level of the antegrade wire ↪. (B) Both wires are seen in the SFA ↪. Via the antegrade sheath ⇨, a snare catheter was used to snare and withdraw the tip of the retrograde guidewire, creating arterial "flossing" across the CTO.* **(Right)** *The "flossing" guidewire was used for PTA & stenting of the CTO. (A) The superficial femoral → and (B) popliteal → arteries are widely patent afterward.*

(Left) *If the distal lumen is not re-entered during subintimal recanalization, a re-entry catheter ⇨ can be used. (A) It is advanced over the guidewire ➡ in the subintimal space. (B) The catheter is oriented toward the patent lumen ➡, & the curved needle ↷ of the catheter is advanced through the intima. A microwire ↷ is placed through the needle into the lumen. (C) The catheter ⇨ is removed.* **(Right)** *(D) A catheter ➡ can be placed over the microwire into the distal lumen, and (E) stenting ↷ or PTA of the CTO can be performed.*

Re-entry Catheters for CTO: Procedure Steps for Use

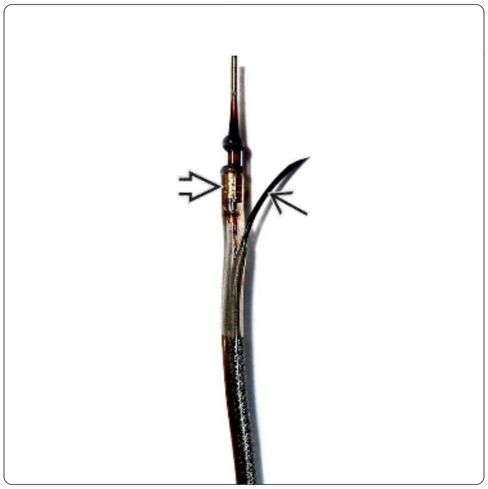


Re-entry Catheters for CTO: Procedure Steps for Use

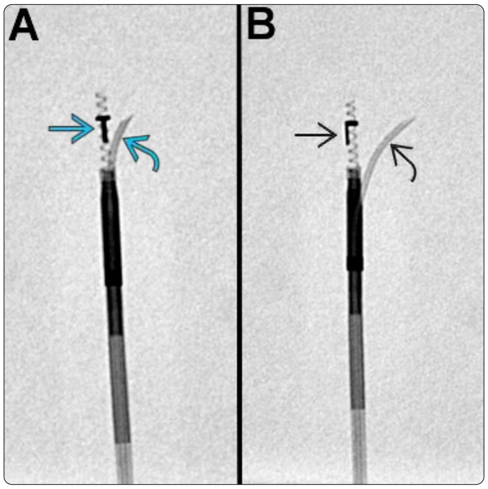


(Left) *The Pioneer catheter has an intravascular US transducer ⇨ that can image the vessel wall & identify the lumen for curved re-entry needle ⇨ deployment during subintimal recanalization.* **(Right)** *Fluoroscopic image of Outback catheter, with the curved needle deployed, shows radiopaque markers used for orientation. (A) If the "T" marker ⇨ is visible, the needle ↷ lacks a 90° orientation to the patent lumen. (B) By rotating the device until the "L" marker ⇨ is seen, the needle ↷ is perpendicular to the lumen.*

Re-entry Catheters for CTO: Pioneer Re-entry Catheter

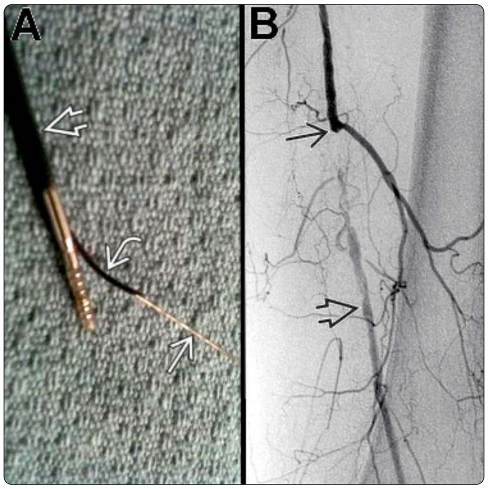


Re-entry Catheters for CTO: Outback Catheter Orientation

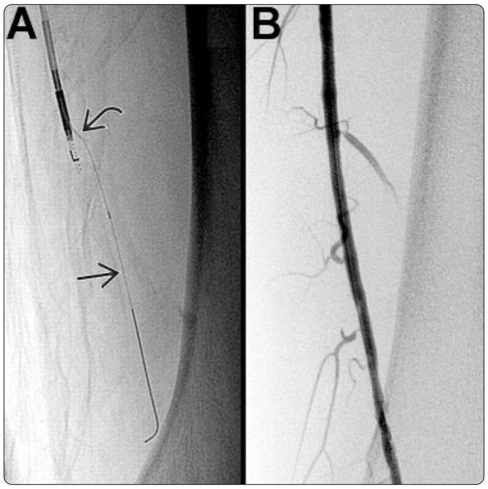


(Left) *(A) Outback re-entry catheter ➡ is shown with the 0.014" guidewire ➡ exiting from the deployed curved 22-g nitinol needle ↷. (B) DSA shows distal left SFA CTO ⇨ with reconstitution of the above-knee popliteal artery ↷. A large collateral may complicate recanalization if the guidewire preferentially enters the collateral.* **(Right)** *(A) The curved re-entry needle ↷ has been advanced into the patent distal lumen, and the 0.014" guidewire ⇨ has been introduced and is intraluminal. (B) After angioplasty and stenting, patency is restored.*

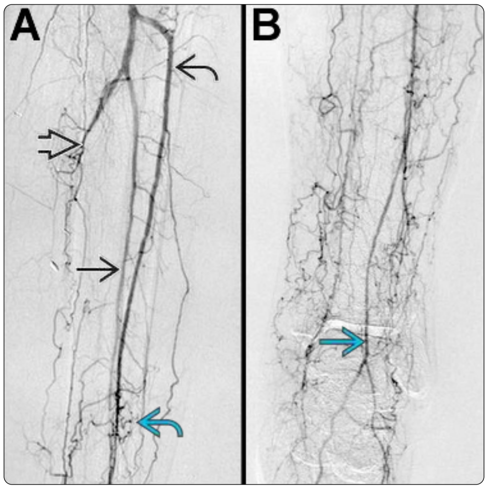
Re-entry Catheters for CTO: Outback Catheter Use in CTO



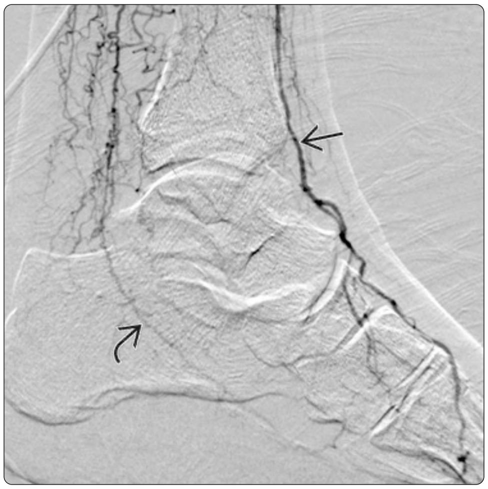
Re-entry Catheters for CTO: Outback Catheter Use in CTO



Intraprocedural Complication: Diagnostic Left Lower Leg DSA

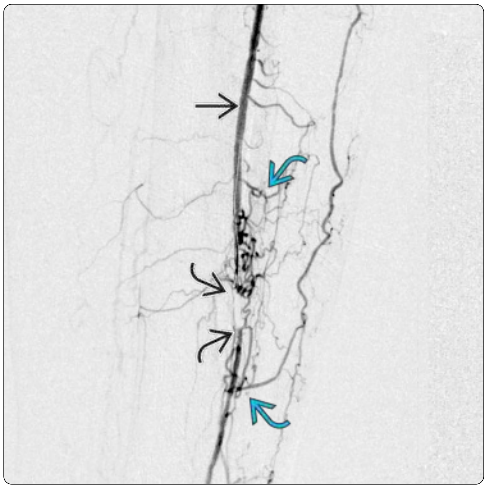


Intraprocedural Complication: Diagnostic Left Foot DSA

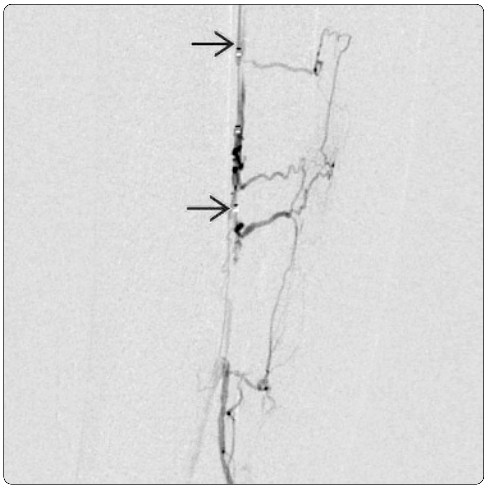


(Left) *Arteriography was performed in a patient with a nonhealing foot ulcer. (A) DSA of the calf shows occlusion of the proximal posterior tibial artery ⇨ with patent anterior tibial ↪ and peroneal → arteries. Prominent collaterals ↪ around the distal anterior tibial artery are present. (B) Ankle DSA shows that the anterior tibial artery extends to the foot as the dorsalis pedis →.* **(Right)** *DSA of the foot in the lateral projection confirms that only the anterior tibial artery → perfuses the foot and there is a poor plantar arch ↪.*

Intraprocedural Complication: Distal Calf Magnification DSA

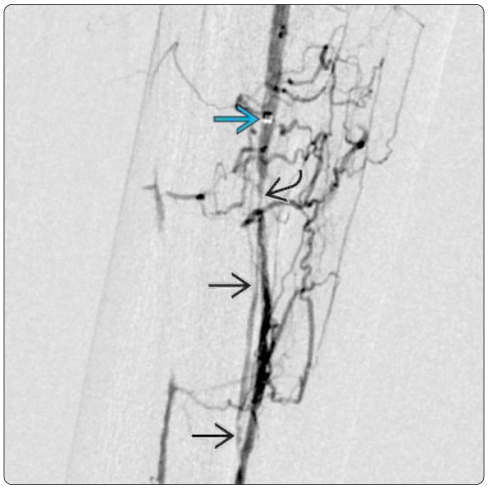


Intraprocedural Complication: Distal Calf Magnification DSA

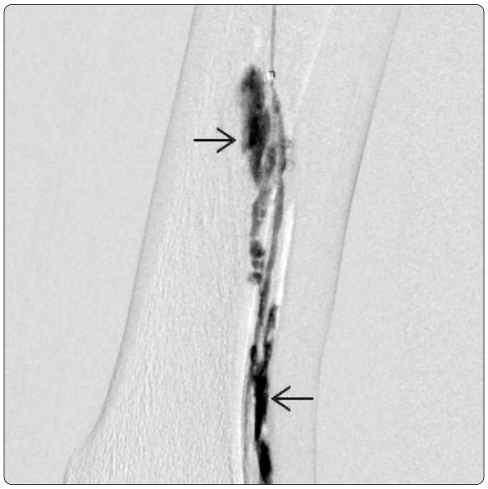


(Left) *After selectively catheterizing the anterior tibial artery origin, a magnification DSA of the calf was obtained, centered at the level of the previously seen collaterals ↪ surrounding the artery distally. DSA shows that there is a short segmental chronic total occlusion ↪ of the anterior tibial artery →.* **(Right)** *A Quick-Cross catheter → was advanced distally in the anterior tibial artery and positioned near the chronic total occlusion, and contrast was injected. This additional magnification DSA more clearly defines the CTO.*

Intraprocedural Complication: Attempted CTO Recanalization



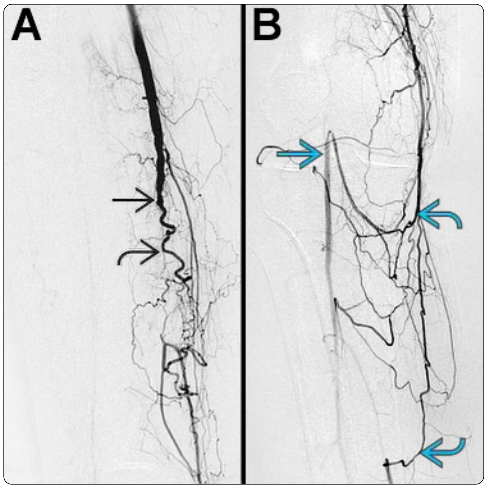
Intraprocedural Complication: Arterial Perforation and Extravasation



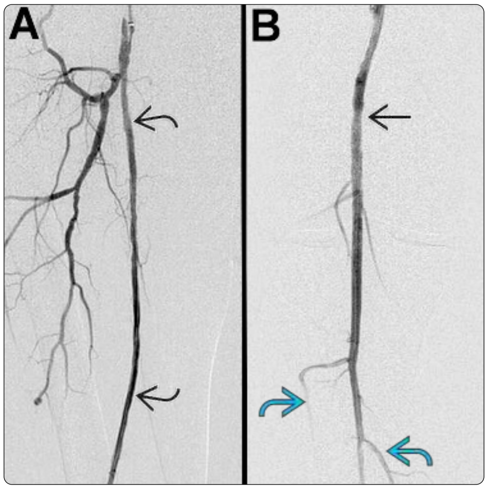
(Left) *A guidewire was advanced through the catheter → and was thought to have created a channel ↪ through the CTO, as seen on this magnification DSA. In retrospect, the guidewire likely created an extravascular channel → that was partially superimposed over the CTO.* **(Right)** *The guidewire was readvanced, but when catheter passage across the CTO was attempted, significant resistance was met. DSA after guidewire removal shows there has been arterial perforation with extensive contrast extravasation →.*

(Left) *DSA of (A) the right SFA shows a chronic total occlusion → distally that ends in a large collateral ↪. (B) This and other collaterals extend inferiorly and reconstitute the popliteal artery → at knee joint level. The collaterals ↪ also extend to the infrapopliteal arteries.* **(Right)** *The CTO was successfully recanalized, and self-expanding noncovered stents were placed along it. (A) DSA of the proximal thigh shows a patent SFA ↪ and (B) patent popliteal artery → with 3-vessel infrapopliteal runoff ↪.*

Delayed CTO Complication: DSA Before CTO Recanalization

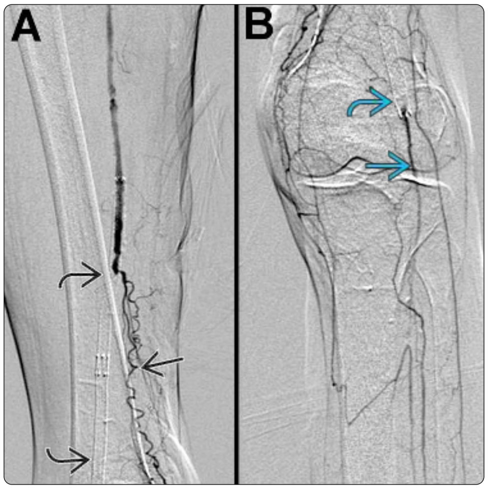


Delayed CTO Complication: DSA After CTO Recanalization

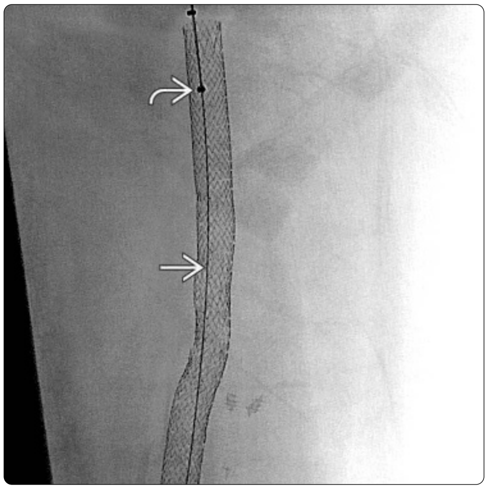


(Left) *The patient did well for 8 months but returned with critical limb ischemia. A noninvasive study could not show flow in the stents. (A) DSA shows stent occlusion ↪ and collaterals →. (B) The popliteal artery → reconstitutes just below the stent ↪. Unfortunately, stent occlusion occurs frequently after CTO revascularization, particularly in long-segment CTOs.* **(Right)** *A guidewire ➡ and catheter ↪ have been advanced into the occluded stent for an attempted secondary intervention to restore patency.*

Delayed CTO Complication: Thrombosis of Intravascular Stent

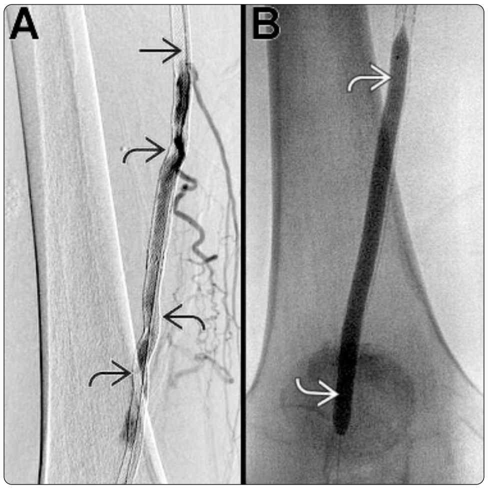


Delayed CTO Complication: Guidewire/Catheter Through Stent

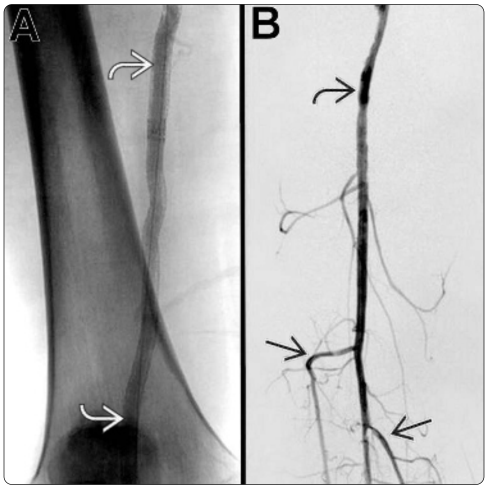


(Left) *The patient underwent catheter-directed thrombolysis. (A) Afterward, contrast injection via the catheter → within the stent shows linear filling defects ↪ reflecting neointimal hyperplasia. (B) A PTA balloon ↪ was used to distend the stent and the hyperplastic intima.* **(Right)** *(A) Angiography after secondary intervention shows restoration of stent patency ↪ with no residual filling defects. (B) The distal portion of the stent ↪ within the popliteal artery is also patent, and there is patent 3-vessel runoff →.*

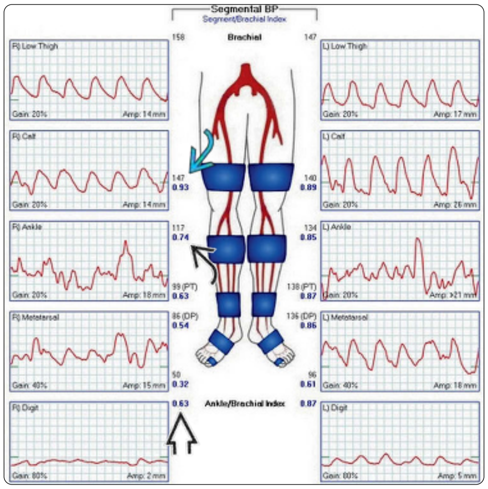
Delayed CTO Complication: Angioplasty of Occluded Stent



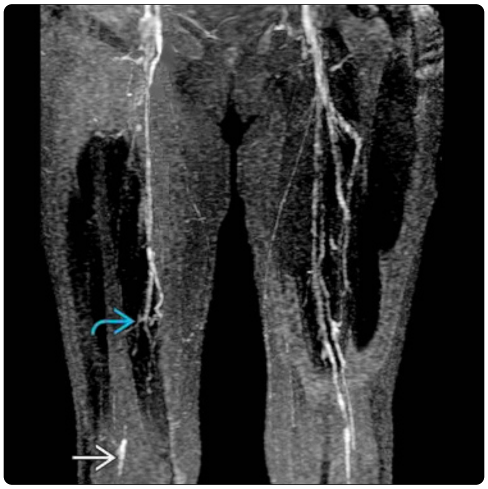
Delayed CTO Complication: Intravascular Stent Patency Restored



CTO of Right Popliteal Artery: Initial US Noninvasive Evaluation

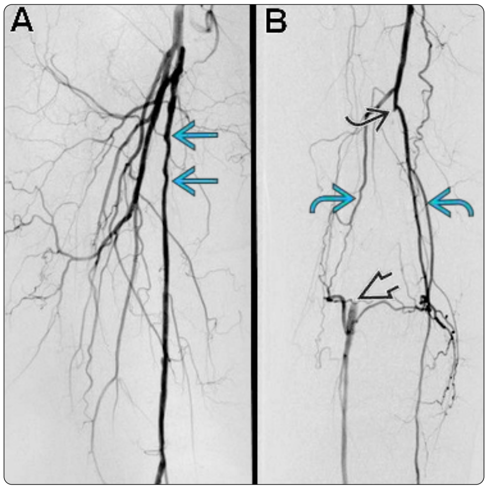


CTO of Right Popliteal Artery: Initial Gadolinium-Enhanced MRA Evaluation

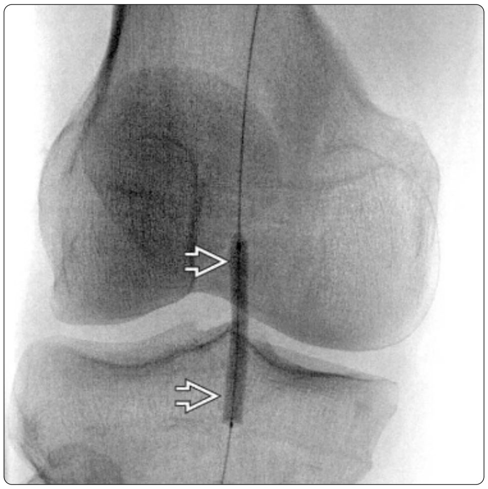


(Left) *Screening US noninvasive examination in a 63-year-old woman with bilateral claudication that was most severe on the right shows a drop in segmental limb pressure from 0.93 in the right thigh ↪ to 0.74 in the calf ↪, consistent with occlusive disease in the distal SFA or popliteal artery. The ankle:brachial index was 0.63 ⇨.* **(Right)** *Gadolinium-enhanced MRA was obtained for further evaluation, confirming distal SFA occlusion ↪ at the adductor hiatus with popliteal artery reconstitution ➡.*

CTO of Right Popliteal Artery: Diagnostic Angiography Prior to Intervention

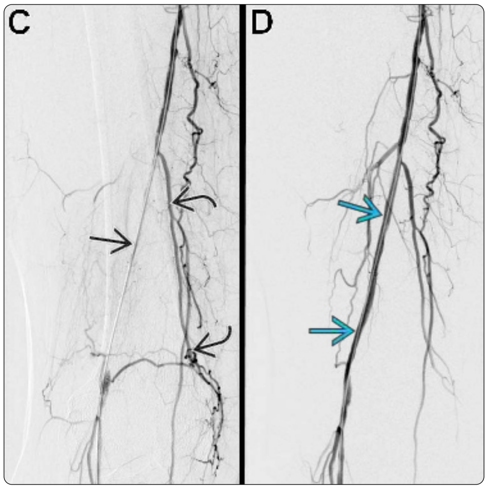


CTO of Right Popliteal Artery: Initial Angioplasty After Crossing Occlusion

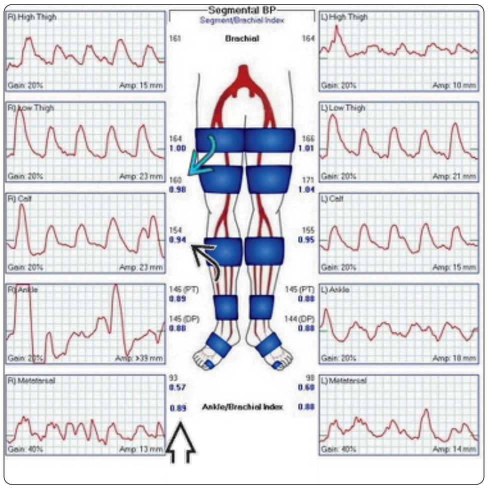


(Left) *Right lower extremity DSA shows (A) a small-caliber but patent SFA with moderate stenoses proximally ⇨. (B) There is occlusion of the SFA distally ↪ at the adductor hiatus. Geniculate collaterals ↪ reconstitute the popliteal artery ⇨ at the level of the patella.* **(Right)** *The popliteal artery CTO was crossed intraluminally. Given the small arterial caliber, drug-coated balloon angioplasty was felt to be a better treatment option than stenting. Initial PTA was performed with a plain 3-mm balloon ⇨.*

CTO of Right Popliteal Artery: Treatment With Drug-Coated Balloon Angioplasty



CTO of Right Popliteal Artery: US Noninvasive Evaluation After Treatment



(Left) *Repeat DSA following angioplasty using a plain 3-mm angioplasty balloon shows (C) a patent lumen with the guidewire → indwelling but preferential flow through the collaterals ↪. (D) After additional angioplasty with a 5-mm drug-coated angioplasty balloon, a normal luminal caliber → is restored to the CTO, with preferential flow reestablished.* **(Right)** *Repeat US noninvasive examination after treatment shows normal pressures at thigh ↪ and calf ↪ levels and an improved ankle brachial index ⇨ of 0.89.*

Abdominal Aortic Endografts

KEY FACTS

TERMINOLOGY

- **Abdominal aortic aneurysm (AAA)**: Localized aortic dilatation exceeding normal diameter by > 50%
- **Endograft** (stent-graft): Fabric-covered self-expanding stent; excludes vascular pathology from circulation
- **Endovascular aneurysm repair (EVAR)**: Endograft placement to treat AAA/other vascular pathology

PREPROCEDURE

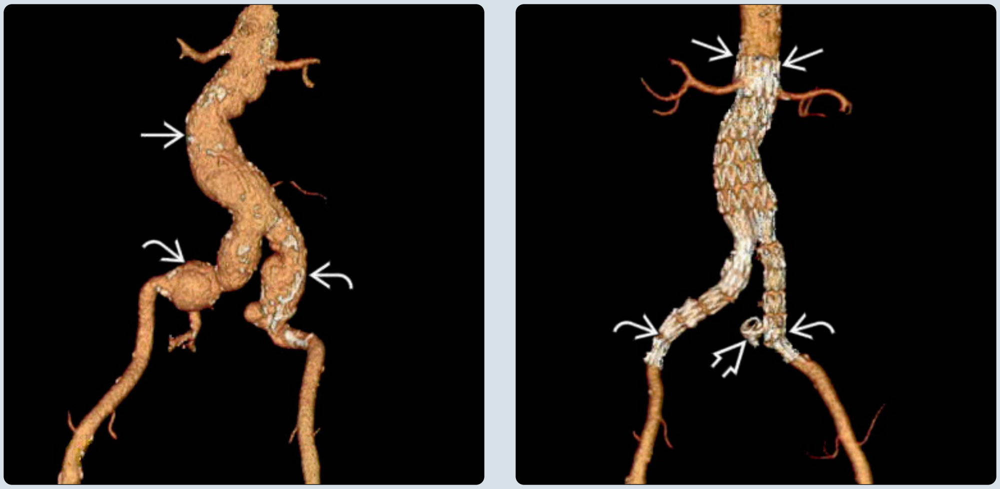
- CTA: Standard imaging tool for AAA evaluation
  - Used for preoperative EVAR planning

PROCEDURE

- Obtain arterial access via 2 separate access sites
  - Percutaneous access vs. surgical cutdown
  - Introduce flush catheter via contralateral access
  - Introduce endograft body via ipsilateral guidewire
- Place endograft below renal arteries; confirm with DSA
- Deploy endograft until contralateral limb dock (gate stub) no longer constrained in delivery system
- Use catheter/guidewire combination to cannulate gate
  - Deploy contralateral limb in planned position
  - Deploy ipsilateral limb of endograft
- Deploy suprarenal stent if applicable
- Use compliant balloon to gently distend all endograft junctions & attachment sites/seal zones
- Obtain DSA; assess for endograft position/endoleak

OUTCOMES

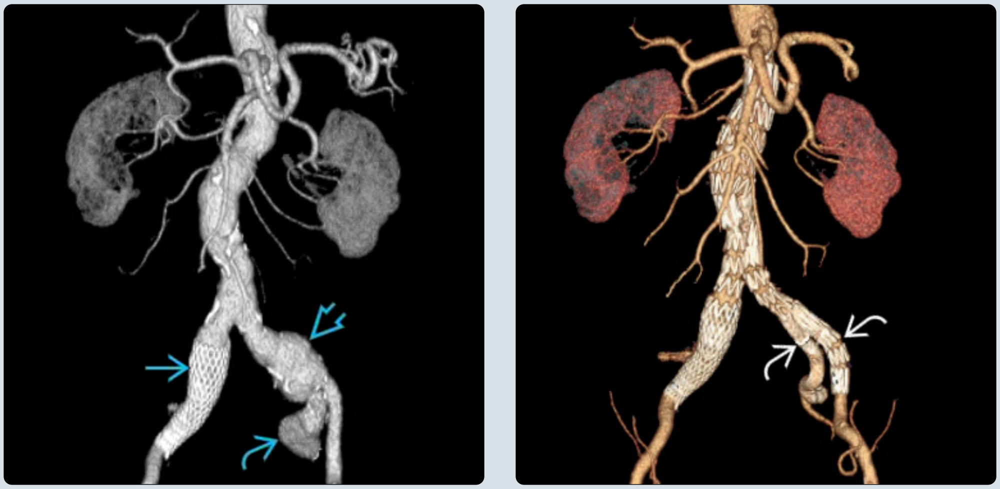
- Technical success (AAA exclusion): 88.8%
  - 30-day mortality: 1.6% EVAR vs. 4.7% surgery
- Delayed complications more common than immediate
  - Type II endoleak most common; usually managed with observation; most spontaneously resolve
- EVAR associated with more secondary interventions than with open surgical aneurysm repair
  - Lifelong surveillance required



Degenerative Aortoiliac Aneurysms

Aortoiliac Aneurysms After EVAR

(Left) *Coronal CECT 3D reformation shows typical degenerative fusiform aneurysms of the abdominal aorta ➡ and bilateral common iliac arteries ↪. Aneurysmal involvement of iliac arteries occurs in ~ 20% of abdominal aortic aneurysms (AAA) & typically increases complexity of EVAR.* **(Right)** *The patient underwent bilateral internal iliac artery coil embolizations ⇨, as complete aneurysm exclusion required distal extension of the limbs ↪ into the external iliac arteries. The endograft has suprarenal fixation ➡.*



Common and Internal IAA Exclusions With Branch Device

Common and Internal IAA Exclusions With Branch Device

(Left) *3D coronal reformation in a patient with left common ⇨ and internal iliac artery ↪ aneurysms (IAA) shows that a right-sided endograft ➡, extending into the external iliac artery, was placed to treat iliac aneurysms. The right internal iliac artery was coil embolized.* **(Right)** *The left-sided aneurysms were treated using an iliac artery branch device ↪, designed to preserve internal iliac artery perfusion, while excluding the aneurysms. Buttock claudication is a known complication of internal iliac artery occlusion.*

TERMINOLOGY

Definitions

- **Abdominal aortic aneurysm (AAA)**: Localized aortic dilatation exceeding normal diameter by > 50%
  - Various etiologies
    - Majority due to multifactorial degenerative process
      - Proteolytic degradation of tunica media; basic pathophysiology of AAA development
      - Significant association with atherosclerosis
      - Genetic influence; high familial prevalence
    - Inflammatory aneurysms occur in up to 10%
      - May be symptomatic with fever & pain
      - May be immune-mediated process
    - Infectious (mycotic) AAA occur in 2%
      - Usually due to local bacterial seeding of diseased aortic wall or seeding via vasa vasorum
      - Known for rapid growth, rupture & high mortality
  - Anatomically classified based on renal arteries
    - **Infrarenal AAA**: Normal aortic segment ≥ 10 mm between renal arteries & most cephalad AAA extent
      - ~ 90% of AAAs occur infrarenally
      - Majority treated using endovascular techniques
    - **Juxtarenal AAA**: Aneurysm extends to renal artery level; normal-caliber aorta above that
      - Evolving endovascular management techniques
    - **Suprarenal AAA**: Involves renal arteries & extends to include superior mesenteric & celiac arteries
      - Complex endovascular &/or surgical treatment
    - AAA may or may not involve iliac arteries
  - Aneurysms also classified by configuration
    - **Fusiform**: AAA involves extended aortic section
      - "True" aneurysm involving all 3 wall layers
      - Typical appearance of degenerative aneurysm
    - **Saccular**: Focal AAA localized to aortic segment
      - May be asymmetrical; may be pseudoaneurysm
      - Infectious aneurysms often have this appearance
- **Iliac artery aneurysm (IAA)**: Abnormal arterial enlargement ≥ 50% of normal vessel diameter
  - Common iliac artery (CIA) aneurysm defined as transverse diameter > 1.5 cm
    - Most iliac artery aneurysms associated with abdominal aortic aneurysms
      - Iliac aneurysms present in roughly 20% of AAA
    - Isolated iliac artery aneurysms uncommon
      - 1-2% of all abdominal aneurysmal disease
    - Internal IAAs rare (≤ 0.4%)
      - Typically associated with aortic & common iliac artery aneurysms
- **Endograft (stent-graft)**: Fabric-covered self-expanding stent; excludes vascular pathology from circulation
  - All endografts have 3 components
    - Delivery system for graft introduction, deployment
    - High radial force, self-expanding, metallic stent framework & attachment system
      - Supports endoprosthesis, attaches to vasculature
    - Impermeable graft fabric surrounding stents
      - Either expanded polytetrafluoroethylene (ePTFE) or woven polyester fabric composition
      - Excludes pathology, provides new conduit
  - Endografts for AAA repair have different methods of fixation to vascular wall
    - Proximal endograft attachment methodology
      - **Suprarenal fixation**: Bare metallic stent extends proximally above fabric-covered endograft; anchors to perirenal arterial tissues
      - **Infrarenal fixation**: No components extend above renal arteries; fixation achieved via radial force of metallic stent which may have barbs
    - Distal endograft attachment methodology
      - Iliac limbs may be straight, flared, or tapered to conform to anatomy; radial force secures limb
  - 3 basic abdominal aortic endograft configurations; modular designs allow combination of components into patient-specific vascular conduits
    - 1-piece graft body & unilateral limb extension; paired with separate contralateral docking limb
      - Forms bifurcated graft; simulates aortic anatomy
      - Most commonly used endograft configuration
    - 1-piece unibody self-expanding endograft; positioned directly upon aortic bifurcation
      - 2nd component extended cephalad; attaches immediately below lowest renal artery
    - 1-piece aorto-uni-iliac endograft
      - Modified bifurcated endograft that extends from aorta to single iliac artery distal attachment
      - Requires surgically created femoro-femoral artery crossover bypass conduit
      - Frequently used during endovascular aneurysm repair (EVAR) for AAA rupture
- **EVAR**: Endoluminal placement of endograft to treat AAA & other pathology
  - Endograft extends proximal & distal to aneurysm
    - Endograft excludes aneurysm from arterial pressure
      - Dilated & weakened aorta is not exposed to flow
      - Aneurysm sac thromboses, negating rupture risk
  - Endograft must attach to relatively healthy arterial tissues proximal & distal to aneurysm sac
    - Must achieve effective seal at attachment sites to exclude AAA from continued perfusion, prevent device migration and progression of disease

Aneurysm Morphology & Vascular Anatomy

- **Aneurysm morphology**
  - **Proximal AAA neck**: Distance between most inferior renal artery and beginning of aneurysm; preferred proximal seal zone for endograft
    - Many features of neck may affect seal
      - Length & diameter
      - Configuration of neck (e.g., straight, conical)
      - Angle between axis of neck & suprarenal aorta
      - Angle between axis of neck & infrarenal AAA
      - Amount of thrombus/calcification in neck
  - **Distal AAA neck**: Distance between caudal aspect of aneurysm & aortic bifurcation
    - Some features of distal neck may affect EVAR
      - Excessively small diameter may limit delivery &/or expansion of endograft components
      - Neck angulation, calcification, & thrombus may impact endograft delivery & deployment
- **Vascular anatomy**

- Aortic branches arising in AAA treatment zone
  - **Celiac artery**: 1st major abdominal aortic branch; arises at lower margin of 12th thoracic vertebra
    - Rarely involved in AAA treatment zone
  - **Superior mesenteric artery (SMA)**: Origin from aorta anteriorly, just below celiac artery
    - Suprarenal stent may extend to/cross origin
  - **Renal arteries**: Paired arteries that typically demarcate upper limit of proximal aortic neck
    - Must preserve renal perfusion during/after EVAR
    - Small accessory renal arteries arising from aneurysm sometimes sacrificed during EVAR
  - **Inferior mesenteric artery (IMA)**: Origin above aortic bifurcation; known cause of type II endoleak
    - Prophylactically embolized by some operators
  - **Lumbar arteries**: Paired vessels arise along dorsal aspect of abdominal aorta at each vertebral level
    - Known cause of type II endoleak
  - **Common iliac artery**: Origin at aortic bifurcation; divides into external and internal iliac arteries
    - Preferred distal seal zone for endograft limbs
  - **External iliac artery**: Extends from common iliac artery bifurcation to inguinal ligament; adequate vessel diameter necessary for endograft delivery
    - Large common iliac artery aneurysm(s) may require limb extension into external iliac artery
  - **Internal iliac (hypogastric) artery**: Originates at common iliac artery bifurcation; has 2 trunks
    - May require embolization or branch device if endograft limb is extended into external iliac artery
  - **Common femoral artery**: Continuation of external iliac artery below inguinal ligament
    - Preferred/usual choice for EVAR arterial access

PREPROCEDURE

Indications

- **Abdominal aortic aneurysm**
  - Size criteria for EVAR intervention
    - Diameter > 5.5 cm (men); > 5.0 cm (women)
    - Diameter > 2x normal aortic diameter
    - Expanding rapidly (> 0.5 cm in 6 months)
  - Symptomatic abdominal aortic aneurysm
    - Acute onset of severe/continuous/worsening middle abdominal &/or back pain
      - Worrisome for impending AAA rupture
    - Ruptured abdominal aortic aneurysm
- **Common iliac artery aneurysm**
  - Diameter > 3 cm
    - No reported ruptures in aneurysms < 3 cm
- **Internal iliac artery aneurysm**
  - No definite size criteria consensus
    - Treatment recommended if ≥ 3 cm

Contraindications

- **General**
  - Uncorrectable coagulopathy
  - History of severe contrast allergy/anaphylaxis
  - Severe renal insufficiency
    - Nondialysis-dependent
    - May consider alternative contrast agent (e.g., CO_2)
  - Systemic infection
    - Risk of endograft infection (rare)
- **AAA**
  - Poor aneurysm anatomy/morphology for EVAR
    - Short, wide, excessively angled AAA neck
    - Circumferential thrombus/calcification in neck
    - Juxtarenal aneurysm
- **Access**
  - Inadequate iliofemoral arterial access for EVAR
    - Highly calcified/small-caliber/tortuous vessels

Preprocedure Imaging

- **CTA**
  - Standard imaging tool for AAA evaluation
  - Accurately demonstrates vascular anatomy
  - Used for preoperative EVAR planning
    - Proximal neck required (nonaneurysmal proximal attachment site for endograft)
      - Need 10-15 mm infrarenal proximal seal zone
      - Determine neck diameter; oversize endograft diameter by 15-20% to ensure good apposition
      - Conical or excessively angled (> 60°) proximal neck problematic; increases type I endoleak risk (a single FDA-approved device is available for neck angulations up to 90°)
      - Excessive thrombus in neck increases risk of poor seal, thrombus displacement into side branches
    - Distal extent of aneurysm significantly impacts treatment, & choice of endograft components
      - Aneurysm may have adequate distal neck near aortic bifurcation, or extend to involve common iliac arteries
    - If aneurysm involves common iliac arteries, must determine where distal seal can be obtained
      - Requires satisfactory distal "landing zones"
    - Assess pelvic arteries used for device introduction
      - Require adequate diameter
      - Extreme tortuosity/thrombus/heavy calcification undesirable

Getting Started

- Things to check
  - Clinical history and physical examination
    - Assess comorbidities that may affect outcomes
      - Stratify patient's cardiac risk before EVAR
      - Other factors (e.g., age, pulmonary/renal status)
    - Comprehensive vascular evaluation
      - Detailed pulse examination/Doppler evaluation
    - Current medications
      - Any anticoagulants, antiplatelet agents, oral hypoglycemic agents, antihypertensives
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - Complete blood count (CBC)
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ratio (INR) ≤ 1.5
- Medications
  - Heparin

        - Various intraprocedural administration regimens
            - Bolus dose of 2,500-5,000 U; followed by infusion of 1,000 U/h
            - Loading dose of 50-100 U/kg; followed by continuous infusion of 15-25 U/kg/h
    - Vasodilator (e.g., nitroglycerin)
        - Typical bolus dose of 100 μg nitroglycerin
        - Prevents/treats catheter-induced vasospasm
- Equipment list
    - Catheters
        - Calibrated ("marker") flush catheter; e.g., pigtail, Omni Flush catheter (AngioDynamics; Queensbury, NY)
        - Selective catheter (e.g., Davis, Simmons)
        - Large, compliant balloon to distend endograft
    - Guidewires
        - Initial "starting" 0.035" guidewire
        - Angled or straight-tipped hydrophilic guidewire
            - Useful in crossing tortuous/stenotic arterial segments or for selective catheterization
            - Often beneficial for gate cannulation
        - Stiff guidewire (e.g., Amplatz, Lunderquist)
            - Serves to straighten tortuous arterial segments
            - Provides stability when introducing/advancing/placing various endograft components
            - Exchange length guidewires typically needed
    - Aortic endografts (available FDA-approved devices)
        - AFX endovascular AAA system (Endologix; Irvine, CA): Unibody modular device
            - Cobalt chromium alloy stent & ePTFE fabric; anatomic fixation on aortic bifurcation & additional suprarenal fixation
        - Aorfix Endovascular Stent Graft (Lombard Medical; Oxfordshire, UK): 2-piece modular device
            - Main body-ipsilateral limb & contralateral limb; self-expanding nitinol stents & woven polyester fabric; stent configuration of series of concentric rings
            - Only AAA stent graft approved for all proximal neck angulations from 0-90°
        - Endurant II AAA stent graft system (Medtronic; Minneapolis, MN): 2-piece modular device
            - Main body-ipsilateral limb & contralateral limb; self-expanding nitinol stents & woven polyester fabric; suprarenal fixation
        - Gore Excluder AAA endoprosthesis (WL Gore; Flagstaff, AZ): 2-piece modular device
            - Main body ipsilateral limb & contralateral limb; self-expanding nitinol stents & ePTFE fabric; infrarenal fixation
        - Ovation Prime Abdominal Stent Graft (Trivascular; Santa Rosa, CA): 3-piece modular device
            - Uses sealing ring technology for endograft fixation, in which customized seal is created by filling conformable O-rings with polymer
        - Zenith Flex AAA endovascular graft (Cook; Bloomington, IN): 3-piece modular device
            - Main body ipsilateral limb & contralateral limb; self-expanding stainless steel stents & woven polyester fabric; suprarenal fixation
    - Stents
        - Noncovered balloon-mounted: Typically permits more precise placement
            - May be needed for ancillary procedures during EVAR (e.g., stenting of iliac/renal artery stenosis)
            - Large-caliber stent [e.g., Palmaz XL (Cordis; Miami Lakes, FL)] sometimes used to enhance seal at proximal endograft attachment
        - Noncovered self-expanding: Conform to varying vessel diameters, can be oversized
            - Also used for ancillary procedures during EVAR
    - Embolic agents
        - Coils
            - Detachable 0.035" or 0.018" embolization coils
            - "Pushable" 0.035" or 0.018" embolization coils
        - Plug-occluding device
            - Amplatzer Plug (St. Jude Medical; St. Paul, MN)
        - Used for ancillary procedures during/before EVAR
            - Internal iliac/side branch artery embolization
    - Closure devices
        - Placed during percutaneous access for EVAR; allows suture-mediated closure after procedure
            - ProStar XL (Abbott Vascular; Abbott Park, IL)
            - Perclose ProGlide (Abbott Vascular)

PROCEDURE

Patient Position/Location

- Best procedure approach
    - Typically bilateral common femoral artery access
        - Large-caliber devices; require adequate arterial diameter for introducing endograft
            - Sheath diameters range from 19-24 Fr
            - Device access site termed "ipsilateral access"
        - Angiographic catheter for DSA imaging can be placed via smaller caliber access artery
            - Catheter access site termed "contralateral access"
    - Access traditionally via surgical femoral arteriotomy
        - General or epidural anesthesia typically used
- Alternative "pre-close" percutaneous access technique; requires suture-mediated closure device placement prior to device/sheath introduction
    - **"Pre-close" technique with ProStar XL device**: Requires 1-2 devices; some advocate single device for 12-14 Fr access & 2 devices if larger
        - Obtain percutaneous access; place guidewire
        - Introduce & deploy ProStar XL device
        - Secure 2 green & 2 white sutures with hemostats
            - Remove device over guidewire
        - If using 2 devices, deploy 2nd device after rotating 60° relative to 1st device
        - Secure additional 4 sutures with hemostats
        - Tie 2 green & 2 white suture pairs after EVAR
            - Use sliding knot technique
    - **"Pre-close" technique with ProGlide device**: Requires 2 Perclose ProGlide devices
        - Obtain percutaneous access; place guidewire
        - Introduce 1st 6-Fr ProGlide device; deploy needles 30° medially or laterally from midline
        - Remove device; secure sutures with hemostats
        - Repeat procedure with 2nd 6-Fr ProGlide device; deploy needles at 60° angle from 1st device

        - Remove device; secure sutures with hemostats
        - Tie sutures after EVAR; use sliding knot technique
- Various other access options described if femoral arterial approach not feasible
    - Retroperitoneal surgical access to common iliac arteries or distal abdominal aorta
        - Direct sheath introduction via exposed arteries
        - May also involve surgical creation of vascular conduit that is anastomosed to iliac arteries/distal abdominal aorta; endograft introduced through conduit

Procedure Steps

- **General**
    - Obtain arterial access via 2 separate access sites
        - For flush catheter & device introduction
    - Introduce flush catheter via contralateral access site
        - Position catheter sideholes at renal artery level
    - Introduce selective catheter via ipsilateral access
        - Place catheter in suprarenal aorta
    - Place stiff guidewire via catheter into suprarenal aorta
        - Stiff guidewire required for endograft placement
    - Introduce endograft body over ipsilateral guidewire
        - Position endograft with fabric-covered edge near expected position of renal arteries
    - Position image receptor; center over endograft
    - Inject contrast via flush catheter; obtain DSA
- **Device deployment** (modular bifurcated devices)
    - Adjust endograft position based on DSA images
        - Must deploy so fabric-covered edge of endograft terminates immediately below lowest renal artery
            - May initially position with fabric slightly above renal arteries, & pull downward during deployment
    - Deploy endograft until contralateral limb dock (gate stub) is no longer constrained in delivery system
    - Remove flush catheter over guidewire
    - Place selective catheter (e.g., Kumpe) over guidewire
        - Use catheter/guidewire combination to cannulate gate stub for contralateral limb
    - Confirm successful cannulation
        - Rotating flush catheter or inflating balloon should meet no resistance if within graft body
    - Obtain DSA of contralateral iliac bifurcation
        - Determine optimal distal "landing zone" for limb
    - Introduce contralateral limb over guidewire; position within gate stub with adequate overlap for seal
        - Deploy contralateral limb in planned position
    - Obtain DSA of ipsilateral iliac bifurcation
        - Deploy ipsilateral limb of endograft
    - Deploy suprarenal stent if applicable
    - Remove device delivery system; leave access sheaths
    - Use compliant balloon to gently distend all endograft junctions & attachment sites/seal zones
    - Place flush catheter in suprarenal aorta
    - Obtain DSA; assess endograft position & endoleak
    - Remove sheaths; close access sites
- **Iliac artery aneurysm(s)**
    - Treatment depends on IAA location/morphology
        - Need 10-15 mm of normal arterial diameter neck above & below aneurysm for seal zones
            - IAA usually treated proximally with bifurcated aortic endograft since most have associated AAA
            - Isolated IAA sometimes treated with tube graft
    - Internal iliac artery embolization
        - Required if common IAA extends to iliac bifurcation & exceeds 25 mm in diameter
            - Must extend distal limb of tube graft into external iliac artery
            - Internal iliac artery embolization needed to prevent retrograde perfusion of IAA
        - Consider staged embolizations for bilateral IAA
            - 1- to 2-week interval between each embolization & before EVAR, allowing collaterals to develop
        - Selectively catheterize internal iliac artery origin
            - Consider approach via contralateral access
            - Cobra catheter configuration often useful
            - Prefer proximal embolization to maximize distal collateralization, maintain pelvic perfusion
            - May use coils or plug occluder to embolize
        - Prefer to preserve internal iliac artery patency if possible; avoids buttock claudication/other issues
            - Requires branched device use/bypass
- **Juxtarenal abdominal aortic aneurysms**
    - Endograft coverage of renal arteries required for adequate proximal fixation; maintaining renal perfusion requires novel techniques
        - "Snorkel" or "chimney" technique: Involves placement of covered stents in branch arteries that will be intentionally covered by endograft
            - Place sheaths in branch arteries via brachial access; position covered stents in arteries
            - Deploy EVAR endograft in desired position
            - Deploy "snorkel" stents; should extend 2-3 cm into branch artery & also extend cephalad above endograft fabric to maintain branch perfusion
        - Fenestrated graft technique: Involves customized endograft placement; investigational devices
            - Referred to by acronym FEVAR (fenestrated endovascular aneurysm repair)
            - Small openings (fenestrations) in endograft are aligned with arteries that will be covered
            - Covered stents placed into branch arteries through openings to maintain perfusion
- **Infected (mycotic) aortic aneurysms and EVAR**
    - EVAR previously felt to be always contraindicated
    - Recent European retrospective multicenter analysis; other literature reviews of outcomes of EVAR for infected aneurysms
        - High morbidity and mortality associated with conventional surgery for infected aneurysms
        - EVAR may be feasible, reasonable alternative in selected cases
            - One study showed 30-day survival rate of 89.6% and 2-year survival rate of 82.2%
            - Late infection-related complications occur, are often lethal; long-term antibiotic treatment and follow-up warranted

Alternative Procedures/Therapies

- Surgical
    - Open surgical aneurysm resection/repair

  - Hybrid surgical/endovascular repair

POST PROCEDURE

Postprocedure Imaging

- Surveillance follow-up imaging imperative
  - CECT/CTA 1 month after EVAR procedure
    - Obtain additional CT 3-6 & 12 months after EVAR
  - If no issues identified, annual imaging thereafter
    - Evaluate images for endoleak & other complications
- Some investigators recommend MR or US imaging in post-EVAR surveillance to avoid contrast & radiation
  - Endograft-related signal void/artifact may limit exam

OUTCOMES

Problems

- EVAR associated with more secondary interventions than open repair; lifelong surveillance required
- EVAR much more costly than open surgical repair
  - Endograft components expensive
  - Typically multiple components used during EVAR

Complications

- Most feared complication(s)
  - Arterial rupture or avulsion (infrequent)
    - Diseased arterial access vessels most susceptible
      - External iliac artery typically involved
- Immediate/periprocedural complication(s)
  - Access site complications (1-10% incidence)
    - Hematoma, pseudoaneurysm, iatrogenic arteriovenous fistula formation & seroma
    - Overall access site complication rates more common with surgical cutdown than with percutaneous access
  - Arterial dissection/thrombosis (3% incidence)
  - Unintentional coverage of critical aortic side branch by endograft (e.g., main/accessory renal artery)
    - May require stenting or surgical bypass
  - Displacement of atheroma/thrombus into aortic side branch during endograft deployment
    - May require surgical/endovascular intervention
  - Contrast-induced nephropathy (7% incidence)
  - Ischemic complications
    - Colonic ischemia (1-3% incidence)
      - High mortality rate of 50% within 1 month
    - Spinal cord ischemia; very rare (0.2% incidence)
- Delayed complication(s)
  - **Endoleak**: Persistent perfusion of excluded aneurysm sac after endograft placement
    - **Type I**: Perfusion of aneurysm sac via incomplete/ineffective seal at endograft attachment site
      - Almost always requires intervention
    - **Type II**: Perfusion of aneurysm sac via arterial branches arising from excluded aortic segment
      - Usually involves lumbar arteries &/or IMA
      - Usually managed with observation; most resolve
    - **Type III**: Perfusion of aneurysm sac due to mechanical problem with endograft (e.g., ineffective sealing/separation of overlapping graft components, rupture/tear of graft fabric)
      - Almost always requires intervention
    - **Type IV**: Perfusion of aneurysm sac due to graft fabric porosity; rarely seen with current endografts
      - Usually transient; managed with observation
    - **Type V**: Continued sac enlargement without identifiable endoleak; also known as endotension
      - May represent endoleak that cannot be identified
  - Buttock claudication (up to 35% incidence)
    - Associated with internal iliac artery embolization
      - Erectile dysfunction reported in up to 17%
      - Gluteal necrosis, colonic ischemia also reported
    - Various strategies exist to preserve internal iliac artery perfusion, & avoid embolization-related complications
      - Bifurcated side branch iliac endograft can preserve internal iliac artery perfusion
      - Surgical internal iliac artery bypass with graft extension into external iliac artery
  - Disease progression at endograft attachment zones
    - May lead to sac enlargement, endoleaks, rupture
  - Limb thrombosis/occlusion (up to 5% incidence)
    - Typically occurs within 1st 2 months
      - Caused by limb kinking, extension of small-caliber limb into external iliac artery
  - Endograft device migration (> 10 mm)
    - Low migration potential in current devices (1-4%)
  - Endograft infection (0.5-1% incidence)
    - Treatment requires endograft & aneurysm resection followed by extraanatomic bypass

Expected Outcome

- Technical success (AAA exclusion): 88.8%
- 30-day mortality: 1.6% EVAR vs. 4.7% surgery

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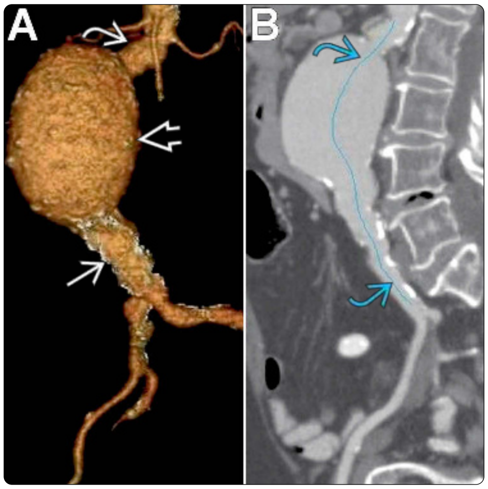
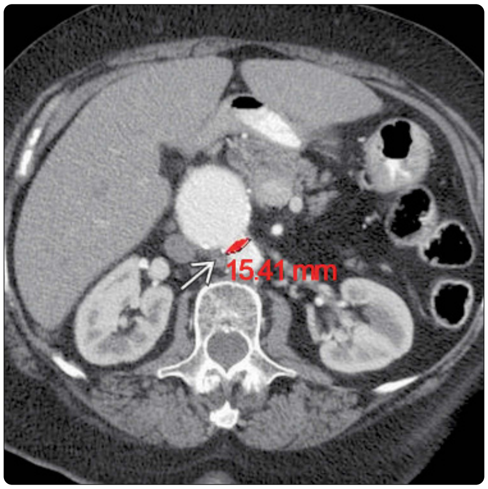
(Left) *CTA is usually used for preprocedure EVAR planning, with critical measurements that must be obtained to determine suitability & select an endograft. (A) 3D reformation shows a saccular infrarenal AAA ➡ with proximal ➡ and distal ➡ necks. (B) A centerline measurement ⇨ simulates how an endograft would align within the treatment zone.* **(Right)** *Axial CECT centered at the proximal neck ➡ shows a transverse diameter of 15.41 cm. The chosen endograft diameter will be oversized by 15-20% to ensure apposition.*

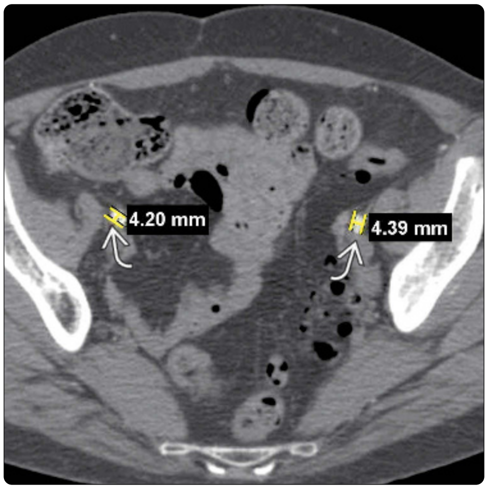


Preprocedure Planning for EVAR

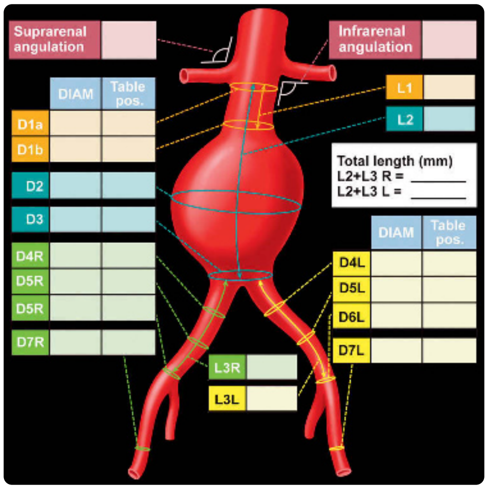


Preprocedure Planning for EVAR

(Left) *The diameter & quality of the iliofemoral arteries must be assessed to determine if an endograft can be safely delivered. In this case, the external iliac arteries ➡ are diminutive & diseased. A minimum diameter of 7 mm is required for most endografts.* **(Right)** *Diameter & length measurements are obtained from the preprocedure CTA, & any areas of angulation are noted. These are recorded on a worksheet that is used to select the modular endograft components that best suit the anatomy. Graphic shows a typical endograft worksheet.*

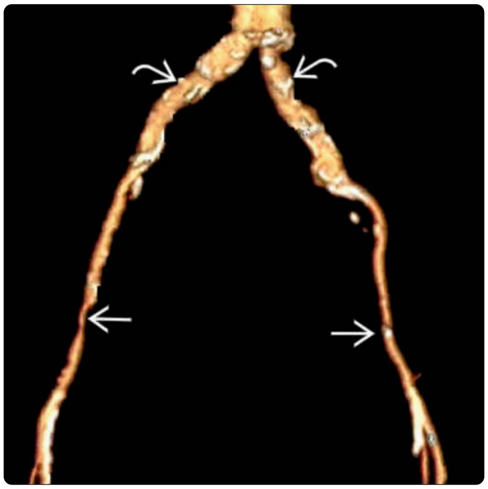


Preprocedure Planning for EVAR (Diameter Measurements With CECT)

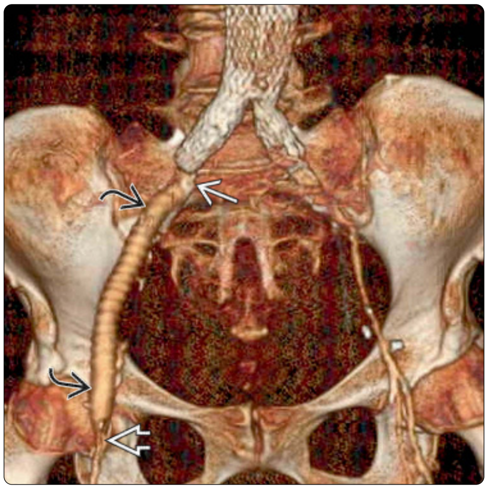


Preprocedure Planning for EVAR (Worksheet for Endograft Selection)

(Left) *CTA reformation shows the diminutive caliber of the diseased external iliac arteries ➡ but shows that the common iliac arteries ➡ are of sufficient size to allow endograft delivery. Based on this information, it was elected to create a surgical conduit for access.* **(Right)** *Via a retroperitoneal approach, a conduit of ePTFE ⇨ was anastomosed end-to-side to the distal right common iliac artery ➡ & was used as access for the endograft. After EVAR, the distal end of the conduit was anastomosed to the common femoral artery ➡.*

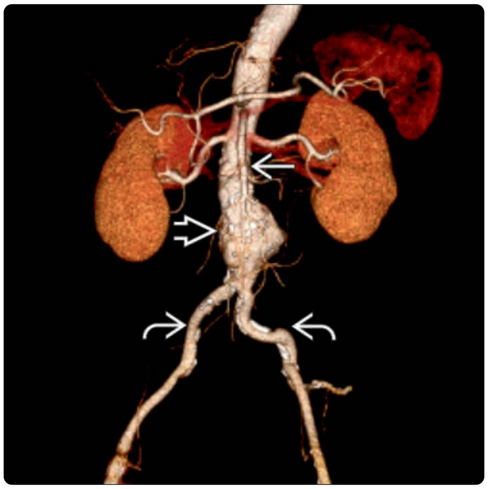


Diseased Arterial Access for EVAR (Evaluation With Preprocedure CTA)

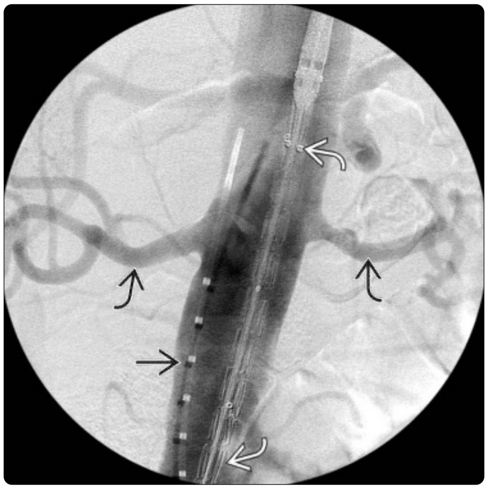


Diseased Arterial Access for EVAR (Surgical Conduit Creation for Access)

Modular Bifurcated Endograft EVAR (Initial AAA Evaluation With CTA)

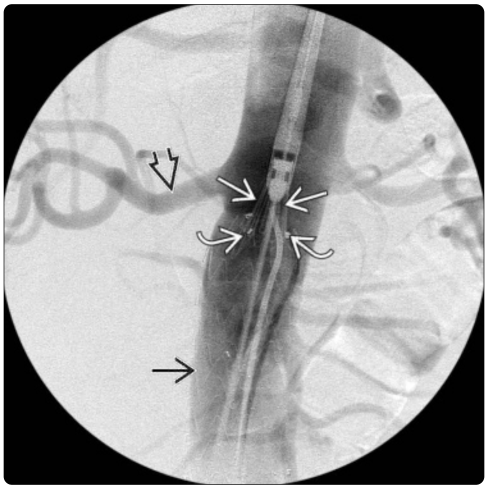


Modular Bifurcated Endograft EVAR (Evaluation of Renal Arteries With DSA)

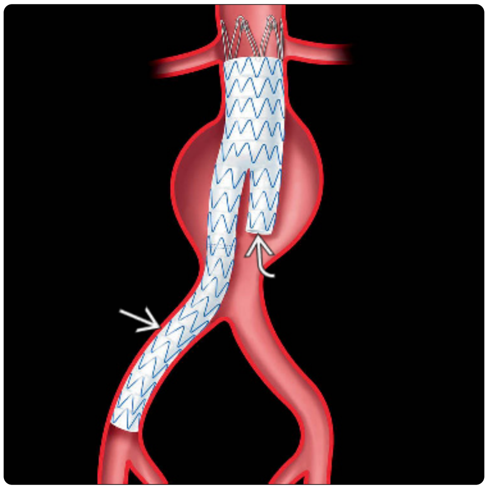


(Left) *CTA shows an AAA ⇨ with a lengthy, nonangulated proximal infrarenal neck →. The common iliac arteries ↪ are tortuous & calcified but nonaneurysmal, & the external iliac arteries are adequate in caliber for endograft delivery. This is an optimal case for EVAR.* **(Right)** *During EVAR using a modular bifurcated endograft, a flush catheter → is placed via a contralateral access. After advancing the endograft ↪ into the upper aorta from an ipsilateral access, DSA via the flush catheter is performed to localize the renal arteries ↪.*

Modular Bifurcated Endograft EVAR (Proximal Deployment of Endograft)

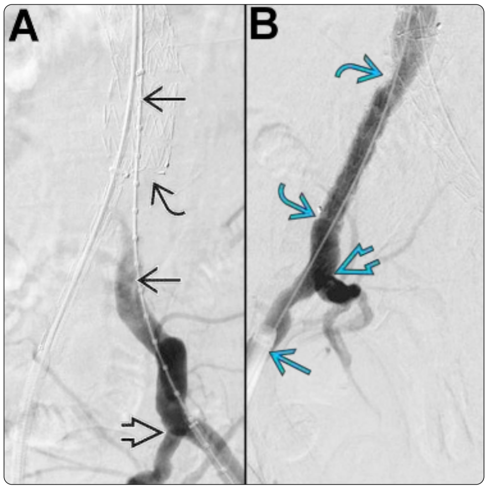


Modular Bifurcated Endograft EVAR (Graphic of Bifurcated Component)

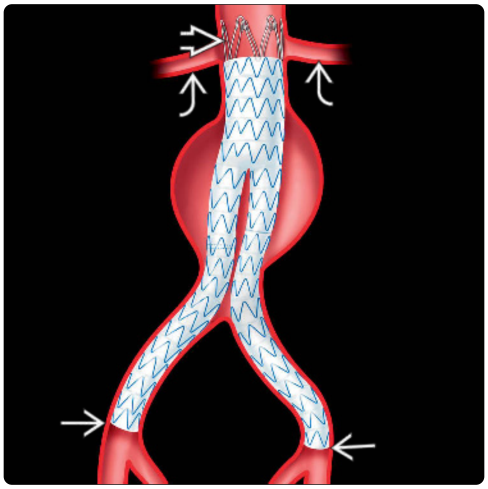


(Left) *Tiny radiopaque markers ↪ delineate the edge of the fabric-covered portion of the endograft. They are positioned just below the lowest renal artery ⇨ & confirmed with DSA. The endograft → is then slowly deployed during continuous fluoroscopy. The noncovered suprarenal stent → remains undeployed.* **(Right)** *The body is deployed until the opening (gate) ↪ for the contralateral iliac limb is no longer constrained in the delivery system, as seen in this graphic. The ipsilateral limb → may be deployed at this time or after gate cannulation.*

Modular Bifurcated Endograft EVAR (Cannulation of Contralateral Gate)

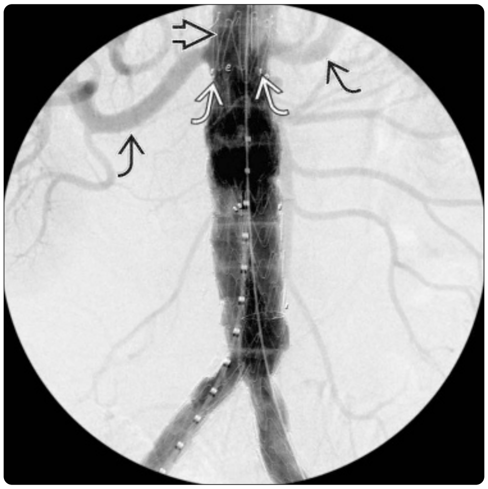


Modular Bifurcated Endograft EVAR (Graphic of Completed Endograft)

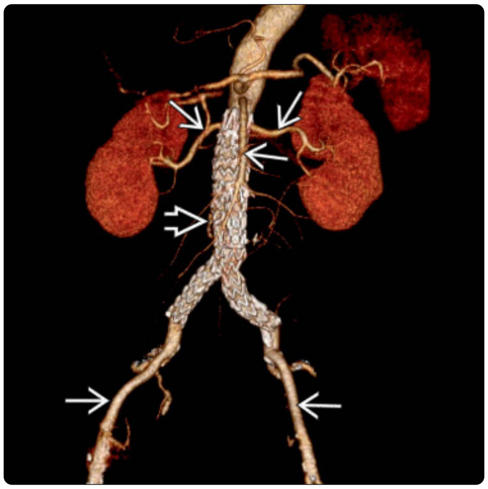


(Left) *(A) The contralateral iliac limb must be docked with the endograft body. This requires cannulating the gate with a guidewire & catheter. DSA shows a catheter → entering the gate ↪ & also delineates the left iliac bifurcation ⇨. (B) DSA via the ipsilateral sheath → shows the right iliac bifurcation ⇨ and the ipsilateral iliac limb ↪.* **(Right)** *Graphic shows the completed endograft. The fabric ends below the renal arteries ↪, the suprarenal stent ⇨ is deployed, & both limbs → extend to the iliac artery bifurcations.*

Modular Bifurcated Endograft EVAR (Abdominal Aortic DSA Post EVAR)

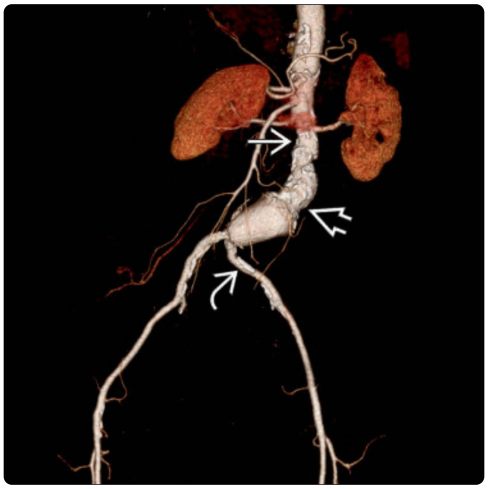


Modular Bifurcated Endograft EVAR (Surveillance CTA Post EVAR)

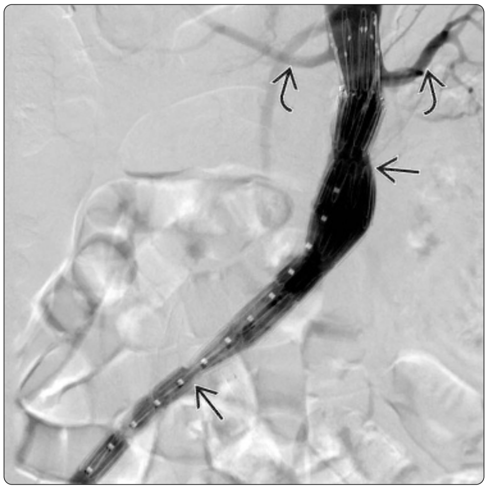


(Left) *After deploying all components, a compliant balloon is used to distend all endograft junctions & attachments. DSA afterward shows the fabric-covered end of the endograft, delineated by radiopaque markers ↪, lies just below the renal arteries ↪. The suprarenal stent ⇨ anchors the endograft.* **(Right)** *Post-EVAR surveillance imaging is imperative, as delayed complications often occur. Axial CECT images were unremarkable and 3D CTA shows the endograft ⇨ is in excellent position & critical vessels → are patent.*

Aorto-Uni-Iliac Endograft EVAR Planning (Preprocedural AAA Evaluation With CTA)

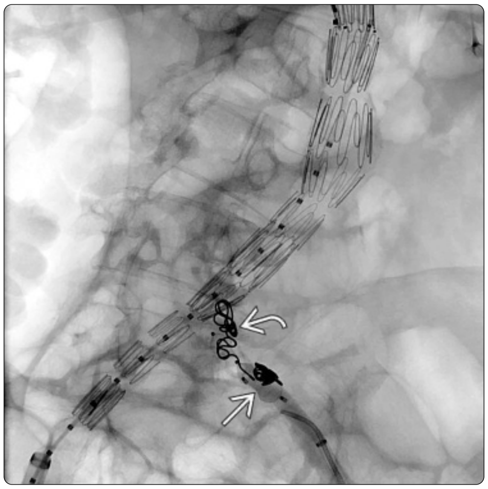


Aorto-Uni-Iliac Endograft EVAR (Angiography After Endograft Placement)

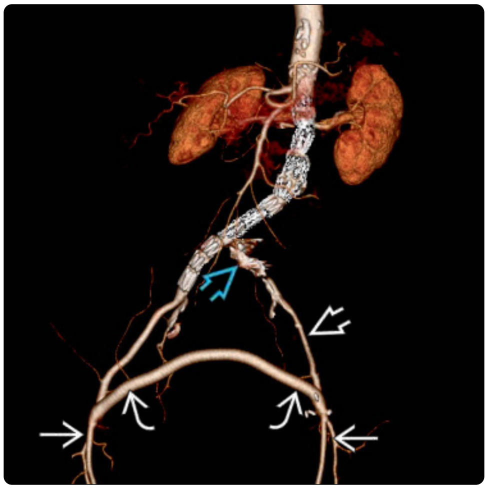


(Left) *CTA shows a tortuous infrarenal AAA ⇨ with no proximal neck → angulation, but acute angles at the aortic bifurcation and left common iliac artery ↪ junction. The small-caliber aortic bifurcation and angulation pose a risk for limb thrombosis if a bifurcated endograft is used.* **(Right)** *EVAR with an aorto-uni-iliac endograft is useful in cases such as this, if there is poor contralateral access, or if there is a ruptured AAA. DSA after EVAR with this endograft configuration → shows AAA exclusion and patent renal arteries ↪.*

Aorto-Uni-Iliac Endograft EVAR (Contralateral Iliac Artery Occlusion)

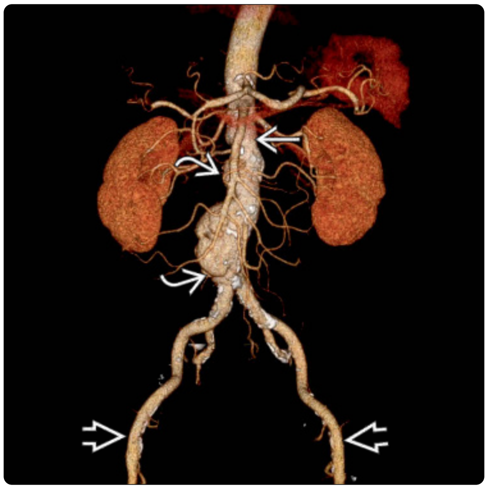


Aorto-Uni-Iliac Endograft EVAR (Surveillance CTA Post EVAR)

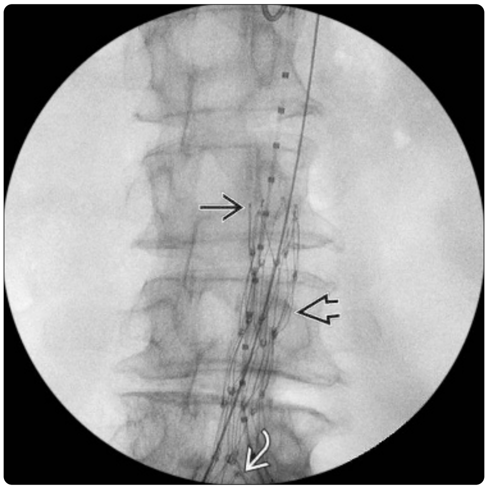


(Left) *In addition to aorto-uni-iliac EVAR, these cases require occlusion of the contralateral common iliac artery with coils ↪ or plug occluders →, to prevent retrograde filling of the AAA sac, and an endoleak.* **(Right)** *Femoral-femoral artery bypass ↪ surgery must also be performed to maintain leg perfusion after occluding the contralateral common iliac artery. As seen on a surveillance CTA, the lower extremity runoff arteries → are patent bilaterally with retrograde filling of the left external iliac artery ⇨ up to the occluder ⇨.*

EVAR With Unibody Endograft

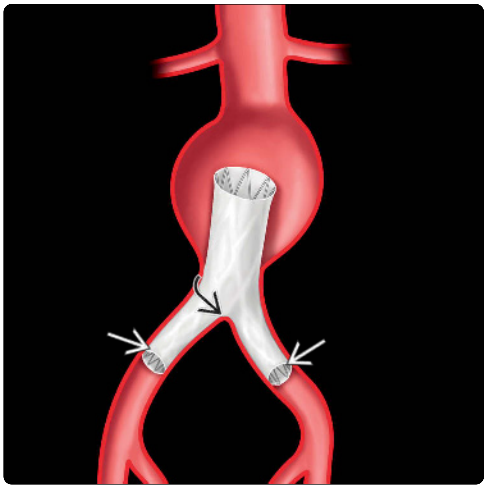


Unibody Endograft Deployment

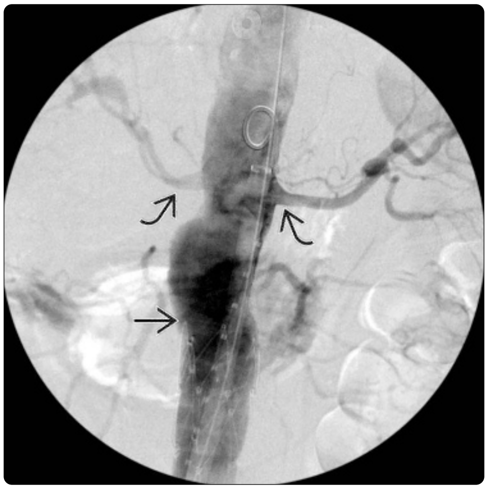


(Left) *CTA shows an infrarenal AAA ↪ extending to the aortic bifurcation without iliac artery involvement. The infrarenal neck → is appropriate in length & caliber for EVAR, as are the access arteries ⇨. Treatment with a unibody endograft was planned.* **(Right)** *EVAR with a unibody device requires first placing the main component on the aortic bifurcation, achieving what is termed "anatomic fixation." A spot image shows the deployed unibody component ⇨ extending from the bifurcation ↪ into the mid aorta →.*

Unibody Endograft Graphic

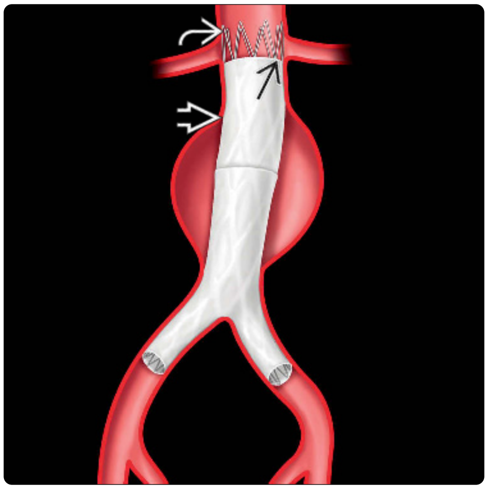


Unibody Endograft Deployment

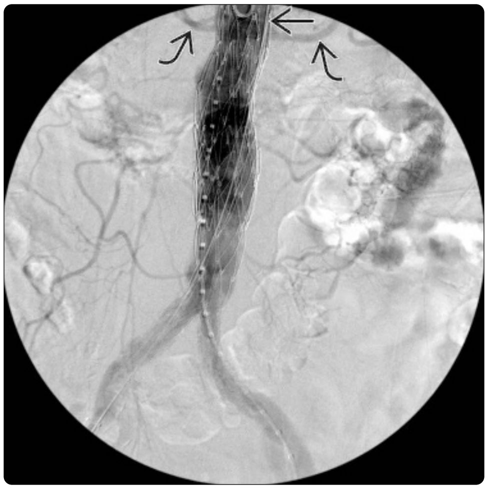


(Left) *Graphic shows the unibody endograft positioned on the aortic bifurcation ↪, with limbs → extending into the common iliac arteries. Device deployment involves snaring a wire via the contralateral access. Traction on the wire is used to pull the contralateral limb into the iliac artery while the remainder of the endograft is deployed via the ipsilateral access.* **(Right)** *DSA after deployment of the 1st component shows that it terminates → well below the renal arteries ↪. An aortic extension cuff will be placed.*

Unibody Endograft Graphic



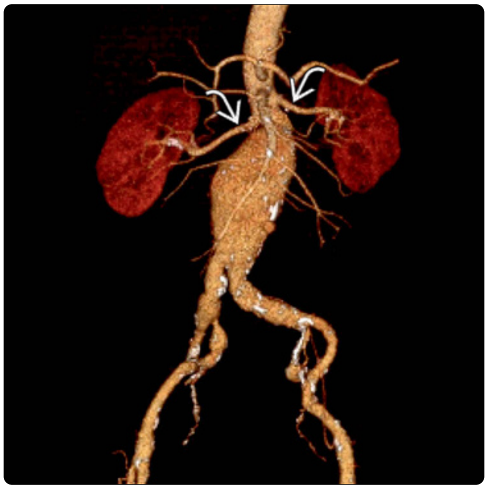
Unibody Endograft Deployment



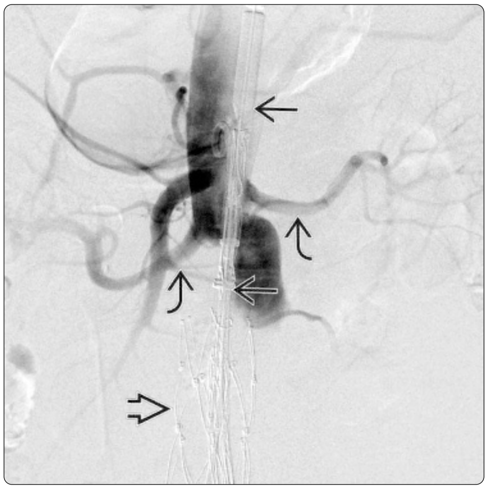
(Left) *Graphic shows the completed unibody endograft after placement of the aortic extension ⇨. It is positioned so that the fabric-covered portion → terminates immediately below the lowest renal artery. The extension shown has a noncovered stent ↪ for suprarenal fixation.* **(Right)** *DSA after placement of the unibody endograft & proximal extension shows AAA exclusion while preserving renal artery ↪ patency. The combination of a suprarenal stent → & anatomic fixation on the aortic bifurcation prevents endograft migration.*

(Left) *CTA shows a juxtarenal AAA adjacent to the renal arteries ⤻. Lack of an infrarenal neck is a contraindication to EVAR using currently approved devices. The patient was not a surgical candidate & was treated with an investigational fenestrated device.* **(Right)** *The Ventana (Endologix) is a fenestrated endograft. After an endograft ⇨ is deployed on the aortic bifurcation, a fenestrated component → is introduced via the unibody & advanced to renal artery ⤻ level. (Courtesy C. Kwolek, MD.)*

Fenestrated Endograft EVAR

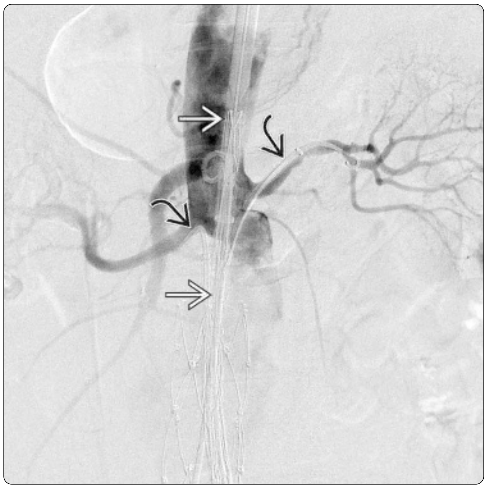


Fenestrated Endograft EVAR

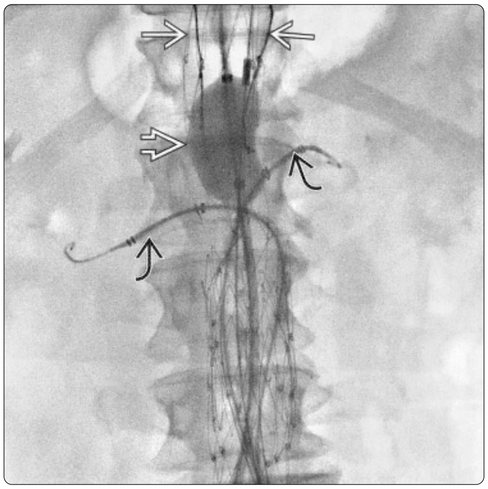


(Left) *Fenestrations in the upper body component ⇨ are placed at renal artery level, & the delivery sheath is withdrawn to expose renal artery cannulation sheaths. DSA shows cannulation of the renal arteries ⤻ via the fenestrations.* **(Right)** *After cannulating both renal arteries, the endograft is positioned so a preformed anterior scallop lies below the SMA, & the suprarenal stent ⇨ is released. After deploying covered renal stents ⤻, a balloon ⇨ is used to distend the endograft components. (Courtesy C. Kwolek, MD.)*

Fenestrated Endograft EVAR

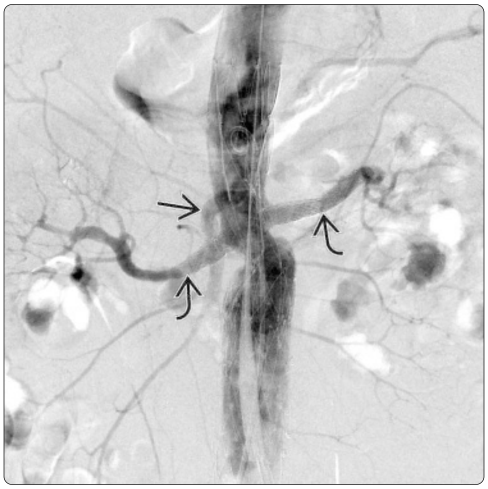


Fenestrated Endograft EVAR

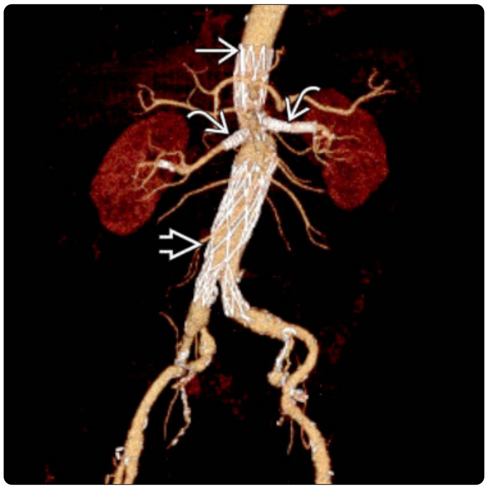


(Left) *DSA after complete deployment of the covered renal artery stents & all endograft components shows a satisfactory outcome. The SMA → & both renal arteries ⤻ are patent & perfused, & the aneurysm has been successfully excluded.* **(Right)** *Surveillance CTA shows the unibody component ⇨ inferiorly, the covered renal artery stents ⤻ that were placed via the fenestrations in the upper body, & the suprarenal fixation stent ⇨. The aneurysm remains excluded by the endograft. (Courtesy C. Kwolek, MD.)*

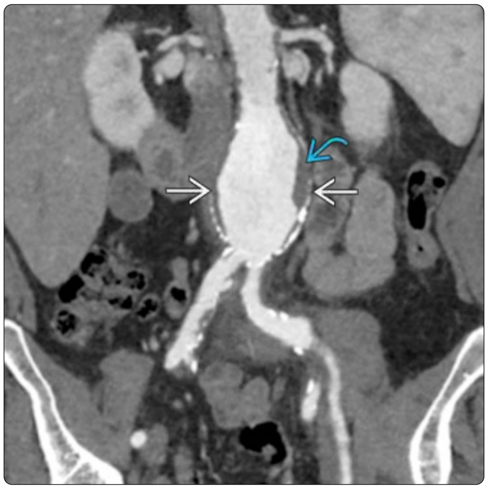
Fenestrated Endograft EVAR



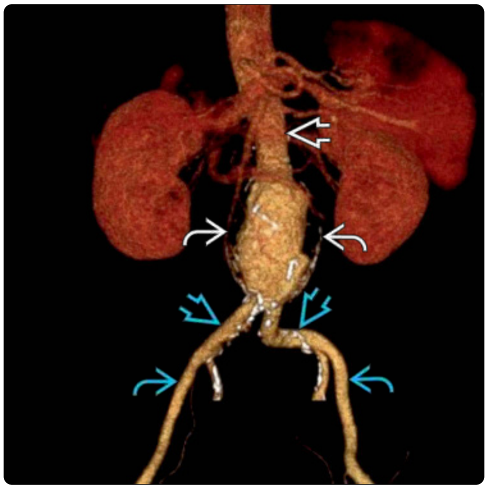
Fenestrated Endograft EVAR



EVAR Using Recently FDA-Approved Endograft (Ovation Prime)

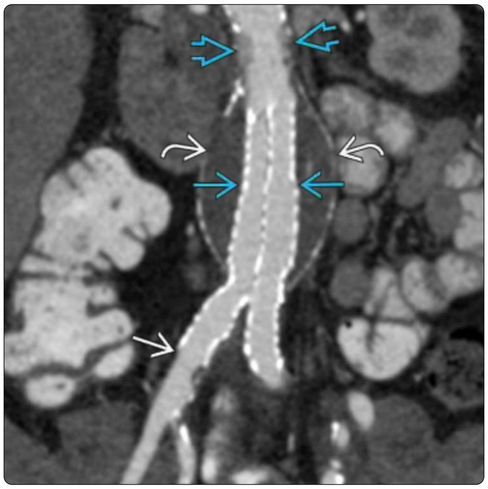


EVAR Using Recently FDA-Approved Endograft (Ovation Prime)

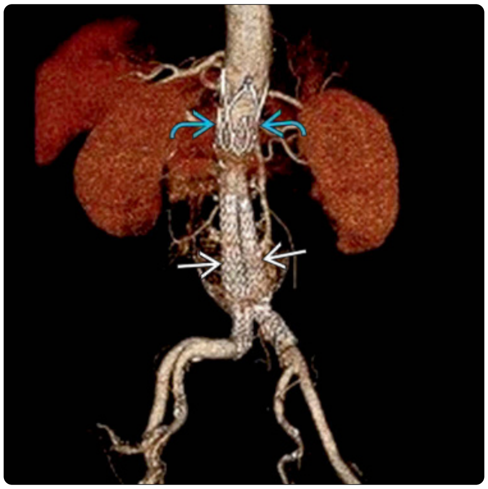


(Left) *This 59-year-old man had a 6-cm infrarenal abdominal aortic aneurysm* ➡ *discovered on an abdominal CT scan that was obtained for his vague abdominal pain. A small amount of eccentric laminar thrombus* ↪ *is seen within the AAA sac.* **(Right)** *3D CECT coronal reformation of the abdominal aorta demonstrates that the aneurysm is saccular* ↪*, has a long and straight infrarenal neck* ➡*, and there are normal-caliber external* ↪ *and common iliac* ⇨ *arteries. These parameters make EVAR a suitable treatment option.*

EVAR Using Recently FDA-Approved Endograft (Ovation Prime)

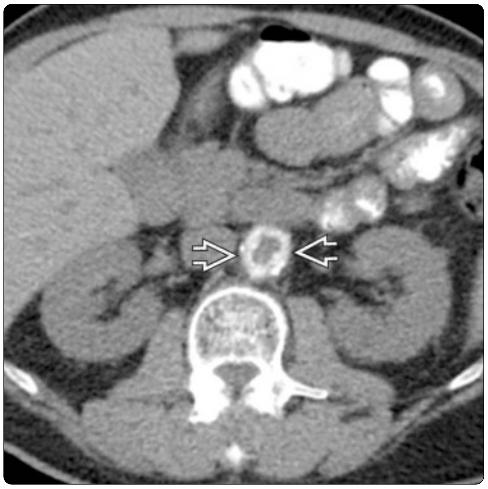


EVAR Using Recently FDA-Approved Endograft (Ovation Prime)

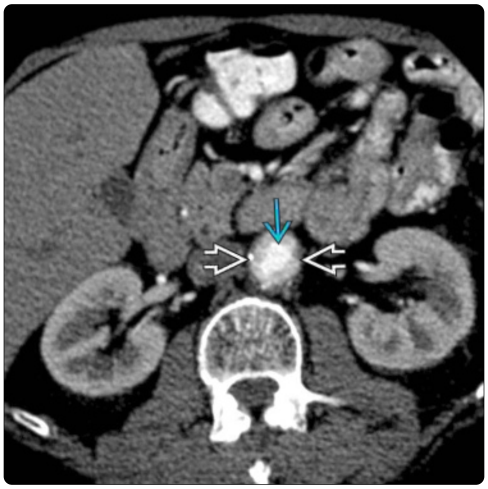


(Left) *Coronal CECT obtained after placement of an Ovation Prime stent graft shows both limbs of the endograft* ⇨ *coursing through the AAA sac* ↪ *with the distal ends terminating in the common iliac arteries* ➡*. Low-attenuation semicircular densities* ⇨ *in the endograft neck represent polymer-filled sealing rings.* **(Right)** *Posterior view from a 3D CECT coronal reformation of the implanted endograft shows the suprarenal stent* ↪*, anchoring the graft proximally in the AAA neck. Both limbs* ➡ *are seen in the AAA sac.*

EVAR Using Recently FDA-Approved Endograft (Ovation Prime)



EVAR Using Recently FDA-Approved Endograft (Ovation Prime)



(Left) *Axial NECT at the level of the AAA neck shows the high-density, polymer-filled sealing ring* ➡ *within the upper portion of the endograft body. This ring conforms to the neck and creates a circumferential seal at the proximal attachment of the endograft.* **(Right)** *Axial CECT at the same level again shows the circumferential sealing ring* ➡ *with contrast* ⇨ *coursing centrally. The sealing ring is designed so as to insulate the neck from blood pressure forces and to aid in preventing a delayed type I endoleak.*

Thoracic Aortic Endografts

KEY FACTS

TERMINOLOGY

- **Thoracic aortic aneurysm (TAA)**: Aortic dilatation exceeding normal diameter by > 50%
    - Considered aneurysm if transverse diameter > 4 cm
    - Increased rupture risk if TAA > 5 cm in diameter
- **Thoracic endovascular aortic repair (TEVAR)**: Endoluminal placement of fabric-covered stent (endograft/stent-graft) to treat TAA/other pathology
    - Endograft excludes aneurysm sac from blood flow
    - Endografts used to treat other aortic pathology (e.g., dissection, aortic trauma, penetrating ulcer)

PREPROCEDURE

- CTA is standard imaging for evaluating aortic pathology; used for preoperative TEVAR planning
    - Assess if left subclavian artery must be covered by endograft to achieve adequate proximal seal

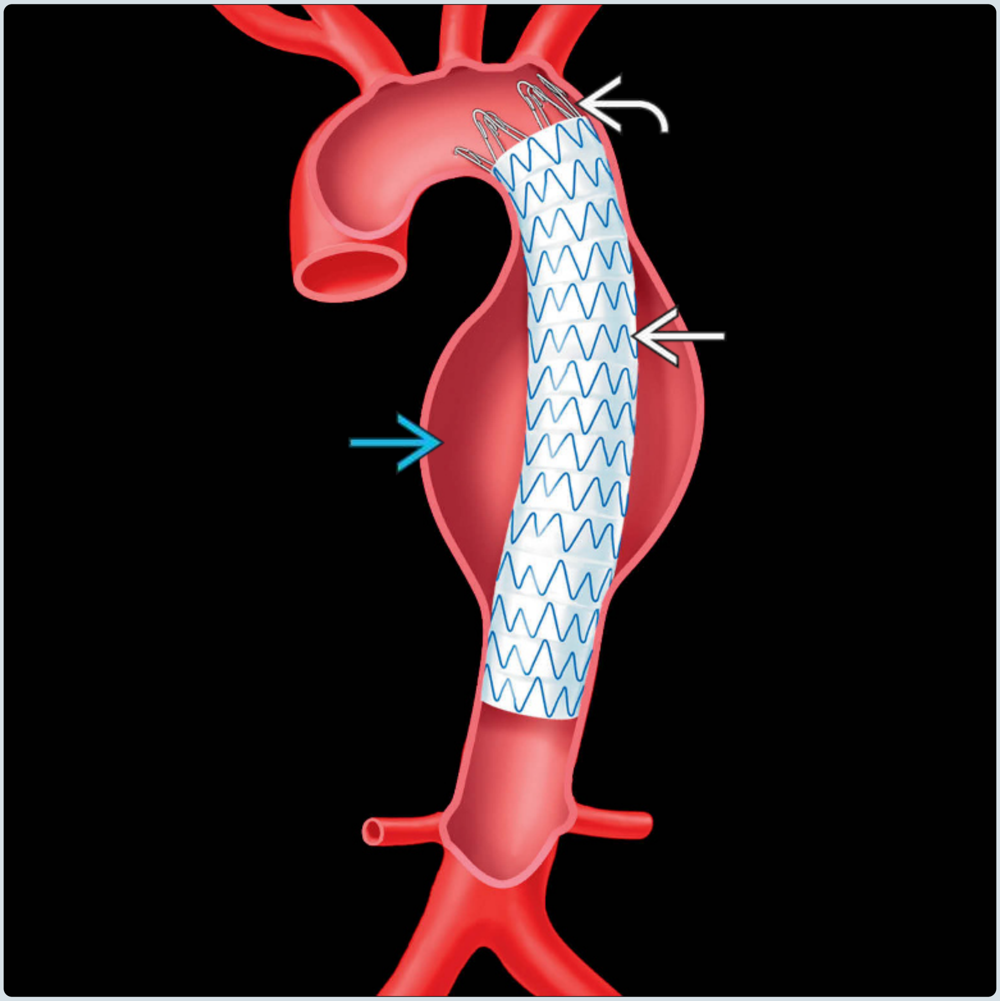
PROCEDURE

- Obtain arterial access via 2 separate access sites
- Introduce flush catheter via contralateral access
- Via ipsilateral access, place stiff guidewire into ascending aorta; required for endograft placement
- Advance endograft to planned deployment position
- Inject contrast via flush catheter; obtain DSA
- Use continuous fluoroscopy while deploying graft
- Proximal endograft deployment can be problematic
    - Curved proximal "landing zone" challenging
    - High-volume blood flow in aorta can displace graft
- Inflate compliant balloon in endograft at seal zones
- Obtain completion DSA

OUTCOMES

- Technical success rate (uncomplicated) 95-98%
- Complications
    - Stroke (3-8% incidence), ↑ if left subclavian covered
    - Spinal cord ischemia (3-6% incidence)

TEVAR: Thoracic Aortic Endograft Repair



Graphic shows a thoracic endograft used in this case to treat an aneurysm of the descending thoracic aorta. The proximal end may or may not have a noncovered stent ↪ that anchors the device. The endograft body is always composed of fabric-covered self-expanding stents ➡, which exclude flow from the underlying aortic aneurysm ⇨.

TERMINOLOGY

Definitions

- **Thoracic endovascular aortic repair (TEVAR)**: Endoluminal placement of fabric-covered stent (endograft/stent-graft) to treat thoracic aortic aneurysm (TAA)/other pathology
  - Endograft extends proximal & distal to aneurysm
    - Aneurysm sac excluded from pressurized arterial blood flowing through endograft
      - Dilated/weakened aorta not exposed to flow
      - Aneurysm sac thromboses; rupture risk negated
- **TAA**: Aortic dilatation exceeding normal diameter by > 50%
  - Considered aneurysm if transverse diameter > 4 cm
    - Increased rupture risk if TAA > 5-cm diameter
      - Rupture risk doubles per 1-cm increment
  - Various etiologies
    - **Degenerative**: Commonly due to atherosclerosis
      - Abnormal matrix metalloproteinase activity
      - Etiology in 75% of TAAs
    - **Connective tissue disorders**: Genetic conditions associated with acute aortic syndromes/aneurysms
      - **Ehlers-Danlos syndrome**: Type IV vascular subgroup characterized by generalized vascular fragility, frequent arterial ruptures
      - **Loeys-Dietz syndrome**: Phenotypically similar to Ehlers-Danlos type IV subgroup
      - **Marfan syndrome**: Cystic medial degeneration; usually involves aortic root (annuloaortic ectasia)
    - **Infection (mycotic)**: Localized infection weakens/compromises integrity of aortic wall
      - Typically saccular configuration
      - Organisms seed aorta via lumen/vasa vasorum
    - **Pseudoaneurysm**: Disruption of 1 or more arterial wall layers; forms contained rupture
      - May be due to aortic injury following penetrating or blunt trauma (e.g., deceleration injury)
      - Also associated with infectious, inflammatory, & neoplastic disease
- **Thoracoabdominal aortic aneurysm (TAAA)**: Extension of TAA distally to involve abdominal aorta
  - Involves visceral arterial segments; highly lethal if untreated but very challenging to treat
- **Thoracic aortic dissection**: Intimal tear extends into aortic wall; blood flow separates wall layers
  - Usually originates in thoracic aorta with varied distribution; may extend into abdominal aorta
  - Blood flow separates aortic wall structures, producing "true" & "false" lumina
  - Weakened wall may rupture; high mortality
- **Penetrating atherosclerotic aortic ulcer**: Plaque rupture through aortic internal elastic membrane
  - Subsequent intramural hematoma may occur
  - Ulcer/hematoma weakens aortic wall; may progress to dissection or form pseudoaneurysm
  - Rupture risk with large ulcer/pseudoaneurysm
- **Intramural hematoma**: Hemorrhage within aortic wall without initial intimal disruption
  - May occur as 1° event in hypertensive patients
  - May result from penetrating atherosclerotic ulcer
  - Intramural hematoma weakens aortic wall; may progress to dissection; increased rupture risk
- **Traumatic aortic injury**: Penetrating or blunt trauma causing various lesions; aortic isthmus is most common site of injury; classified by lesion
  - Grade 1: Intimal tear
  - Grade 2: Intramural hematoma
  - Grade 3: Pseudoaneurysm
  - Grade 4: Rupture

Pertinent Vascular Anatomy

- Thoracic aortic arch divided into zones based on great vessel origins; described as Ishimaru zones 0-4
  - **Brachiocephalic (innominate) artery**: 1st branch of thoracic aorta; originates in Ishimaru zone 0
    - Divides into right common carotid & right subclavian arteries; latter yields vertebral artery
  - **Left common carotid artery**: 2nd branch of thoracic aorta; originates in Ishimaru zone 1
    - Divides into external & internal carotid arteries
  - **Left subclavian artery (LSA)**: 3rd branch of thoracic aorta; originates in Ishimaru zone 2
    - Yields left vertebral artery
  - Thoracic aortic arch distal to LSA described as Ishimaru zone 3
  - Descending thoracic aorta beyond arch curvature described as Ishimaru zone 4
    - Further subdivided into 9 subsegments based on thoracic vertebral segments T4 to T12

PREPROCEDURE

Indications

- **TAA**
  - Typically requires repair when diameter exceeds 6 cm or if patient is symptomatic
- **TAAA**
  - Treated via open, endovascular, or hybrid techniques
    - Investigational fenestrated &/or branched design endografts often needed for endovascular repair
    - Hybrid technique involves debranching, bypass & reimplantation of aortic side branches followed by endovascular exclusion with endografts
  - Same size criteria, symptom indications as for TAA & abdominal aortic aneurysms (AAA)
- **Thoracic aortic dissection**
  - 2 classification schemes based on aortic distribution
    - Stanford classification (most commonly used)
      - Stanford A: Dissection involves ascending aorta
      - Stanford B: Ascending aorta not involved
    - DeBakey classification
      - DeBakey I: Entire thoracic aorta (ascending & descending) involved, ± abdominal aorta
      - DeBakey II: Originates in & confined to ascending aorta, up to innominate artery
      - DeBakey III: Originates in descending aorta; extends distally & may include abdominal aorta
  - Stanford A & DeBakey I & II dissections typically require surgical/endovascular intervention
    - Surgical/endovascular graft with concurrent aortic valve replacement when necessary
  - Stanford B & DeBakey III dissections managed medically unless complications occur, including

    - Compromised arterial perfusion due to compressed true aortic lumen; resultant ischemia
      - Restore arterial perfusion to ischemic vascular territories & end organs
    - Aneurysm formation, rupture/signs of impending rupture (e.g., disease progression, chest/back pain)
    - TEVAR used to cover entry tear & eliminate inflow to false lumen; allows false lumen to thrombose
      - Procedure of choice in acute type B dissection
      - More challenging/less widely accepted in treatment of chronic type B dissection
- **Traumatic thoracic aortic injury**
  - Deceleration injuries fatal in 80-90% of cases
    - Usually cause transmural laceration/rupture
  - Contained rupture/pseudoaneurysm may occur (rare)
    - High mortality if surviving patient untreated
  - Penetrating aortic trauma may also cause disruption, pseudoaneurysm, or transection
- **Intramural hematoma**
  - May be precursor to aortic dissection
    - Often managed medically by aggressive blood pressure reduction using β-blockers
    - Consider intervention if progresses to dissection
  - Worse prognosis if associated penetrating ulcer
- **Penetrating atherosclerotic aortic ulcer**
  - Increased ulcer depth/diameter predicts disease progression; significant aortic wall weakening
    - Can lead to dissection, pseudoaneurysm, & rupture; consider endovascular/surgical intervention
  - Increased rupture rate if symptomatic (38%)
    - Intervention for refractory/recurrent symptoms

Contraindications

- General
  - Uncorrectable coagulopathy
  - Severe renal insufficiency
    - Nondialysis dependent
  - History of severe contrast allergy/anaphylaxis
- Endograft device related
  - Allergy to endoprosthesis component materials
  - Inadequate access for device introduction/placement
  - Poor anatomy for endograft placement (e.g., inadequate proximal/distal seal zone)
    - Endograft coverage of LSA may be used to extend proximal seal zone
- Acute aortic syndromes
  - Asymptomatic aortic dissection, intramural hematoma, or penetrating atherosclerotic ulcer
    - May be medically managed; requires close clinical & imaging surveillance to assess for progression
- Benign processes: Mimicking acute aortic injury
  - **Aortic spindle**: Slight circumferential bulge of distal aortic arch immediately beyond isthmus
  - **Ductus diverticulum**: Focal, smoothly marginated bulge along inferomedial aspect of aortic isthmus
    - Occurs in 9% of adult patients
  - **Infundibulum of aortic branch origin**: Conical shape to vessel origin from thoracic aorta
    - Typically involves brachiocephalic, left subclavian, or bronchointercostal arteries

Preprocedure Imaging

- Chest radiography
  - Findings in acute thoracic aortic injury
    - Widened mediastinum & apical cap
    - Displacement of trachea, left mainstem bronchus, or nasogastric tube by hematoma
- CTA
  - Standard imaging tool for evaluation of TAA, dissection, penetrating ulcer, traumatic aortic injury
  - Accurately demonstrates vascular anatomy; used for preoperative TEVAR planning
    - Requires satisfactory proximal landing zone
      - Need 20-mm proximal seal zone
      - Graft should appose inner curve of aortic arch
    - Assess if LSA must be covered by endograft to achieve adequate proximal seal zone
      - May require revascularization via left common carotid to LSA bypass
    - May determine if debranching of aortic arch needed to achieve adequate proximal seal zone
      - Allows more proximal positioning of endograft
    - Requires satisfactory distal landing zone
      - Need 20-mm distal seal zone
      - Preferable not to cover celiac axis if possible
  - Endograft choice based on CTA measurements
    - Endograft diameter based on true aortic short axis
      - Determination of aortic diameter at levels of proximal & distal seal zones of endograft
    - Determination of length of coverage required
    - Assessment of aortic angulation/tortuosity
    - Mural/luminal characteristics of aorta (e.g., thrombus burden, calcifications)
    - Characterization of access vessels
      - Arterial diameters, tortuosity, & calcifications
- MRA
  - Excellent delineation of arterial anatomy & pathology
    - Can avoid using iodinated contrast media
  - Extremely accurate for diagnosis & staging of dissection
    - Ability to use cine imaging sequences helpful
      - Detection of aortic insufficiency
  - Long scanning times problematic in unstable patients
- DSA
  - Somewhat limited role in preprocedure evaluation
  - Primary imaging guidance during intervention

Getting Started

- Equipment list
  - Thoracic endografts
    - TAG endoprosthesis (W.L. Gore; Flagstaff, AZ): Nitinol & expanded polytetrafluoroethylene
    - Relay Plus (Bolton Medical; Sunrise, FL)
    - Valiant/Talent thoracic stent-graft (Medtronic; Santa Rosa, CA)
    - Zenith TX2/Alpha endovascular graft (Cook Medical; Bloomington, IN)
  - Thoracoabdominal endografts
    - Limited to investigational device exemption studies

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Typically common femoral artery access used
    - Large-caliber devices; require adequate arterial diameter for introducing endograft
      - Sheath diameters of 22-27 Fr
      - Device access site termed ipsilateral access
    - Angiographic catheter for DSA imaging can be placed via small-caliber access arteries
      - Common femoral or brachial artery access
      - Catheter access site termed contralateral access
  - Access traditionally via surgical femoral arteriotomy
    - General or epidural anesthesia typically used
  - Alternative "preclose" percutaneous access technique
    - Requires suture-mediated closure device placement prior to introducing large femoral access sheath
  - Various other access options available if femoral arterial approach not feasible
    - Retroperitoneal surgical access to common iliac arteries or distal abdominal aorta
      - Direct sheath introduction via exposed arteries
      - May also involve surgical creation of vascular conduit to iliac arteries/distal abdominal aorta
    - Antegrade access via surgical conduit anastomosed to ascending aorta also described
      - Useful in patients who need surgical debranching

Procedure Steps

- **Device selection**
  - Choice typically based on preprocedure imaging
    - Oversize endograft diameter by 10-15%
      - Provides good apposition to aortic wall
- **General**
  - Sterilely prepare/drape intended access sites
  - Obtain arterial access via 2 separate access sites
    - For flush catheter & endograft introduction
  - Introduce flush catheter via contralateral access site
    - Position catheter in ascending aorta
  - Place "starting" guidewire via ipsilateral access site
    - Introduce selective catheter over guidewire
      - Place catheter in ascending aorta
  - Remove starter guidewire; place stiff guidewire via catheter into ascending aorta
    - Stiff guidewire required for endograft placement
  - Place delivery sheath in aorta over stiff guidewire
    - Introduce endograft over guidewire via sheath
  - Position image receptor into left anterior oblique (LAO) projection
    - Optimizes vascular anatomy for TEVAR
  - Advance endograft to planned deployment position
  - Inject contrast via flush catheter; obtain DSA
    - Review images for optimal endograft position
- **Device deployment**
  - Use continuous fluoroscopy during deployment
    - Radiopaque markers on device for positioning
  - Proximal endograft deployment can be problematic
    - Curved proximal "landing zone" challenging
      - Endografts relatively stiff & have long segments; conform poorly to highly angulated/curved arch
      - High-volume blood flow in aorta can displace graft distally before complete deployment
    - Lack of endograft apposition to lesser curve of aortic wall results in "bird-beak" configuration
      - Wedge-shaped gap between endograft undersurface & lesser curvature of aortic wall
      - Risk factor for proximal stent-graft collapse
      - Significantly increases type I endoleak risk
      - Contributes to risk for type II endoleak involving intentionally covered LSA
  - Deploy any additional overlapping components
  - Inflate compliant balloon in endograft at seal zones
    - Apposes endograft to aortic wall, improves seal
    - Also balloon any overlapping component junctions
  - Obtain completion DSA
    - Evaluate endograft position/exclude endoleak
  - Remove catheters/sheaths; obtain hemostasis
- **LSA management during TEVAR**
  - Endograft coverage of LSA needed in up to 40% of cases to obtain adequate proximal seal; routine LSA revascularization controversial
    - Studies supporting routine preoperative LSA revascularization show coverage has increased stroke, paraplegia, or arm ischemia risks
    - Other studies show that LSA coverage without revascularization usually does not have increased morbidity; advocate selective revascularization (e.g., for dominant/isolated left vertebral artery, functioning left arm dialysis fistula, left internal mammary-coronary artery bypass)
      - Some also advocate revascularization for left-handedness, aberrant left vertebral artery origin from arch, prior abdominal aortic surgery
  - Society for Vascular Surgery suggests LSA revascularization in elective TEVAR; recommends strongly if critical perfusion could be compromised
  - Preoperative CTA imaging of vertebral arteries & circle of Willis helpful for assessing anatomy
  - Some investigators propose intraoperative test occlusion of LSA to predict potential ischemia
- **TAAA repair**
  - TAA extension to involve infradiaphragmatic abdominal aorta requires thoracoabdominal repair
    - May require intentional celiac artery coverage
      - Must confirm adequate visceral collaterals; requires surgical debranching if inadequate
      - Must preserve superior mesenteric artery patency
    - Visceral arterial debranching adds formidable complexity; increased morbidity & mortality

Alternative Procedures/Therapies

- Radiologic
  - Use of fenestrated/branch endograft technology
  - Endovascular fenestration of aortic dissection
- Surgical
  - Open surgical thoracic aortic repair
  - Hybrid procedures: Combined open surgical & endovascular repair of aortic pathology

POST PROCEDURE

Things to Do

- Admit to ICU for postprocedure monitoring
  - Monitor arterial access sites for complications
    - Bleeding, expanding hematoma, pulse loss
  - Carefully monitor blood pressure, pulse rate
  - Observe for symptoms/signs of stroke, paraplegia, mesenteric/lower extremity ischemia
- Hospital discharge on postoperative day 1 or 2 is typical

Post Procedure Imaging

- Follow-up CECT/CTA 1 month after TEVAR procedure
  - Surveillance follow-up imaging imperative
    - Obtain additional CT 3-6 & 12 months after TEVAR
  - If no issues identified, annual imaging thereafter
    - Evaluate images for endoleak/other complications
  - More frequent imaging surveillance recommended in cases with "bird-beak" or large endoleak
- Some investigators recommend MR, especially in post-TEVAR dissection surveillance/young patients
  - Endograft-related signal void/artifact may limit exam

OUTCOMES

Problems

- Poor endograft apposition to aortic arch curvature particularly problematic in young patients with traumatic aortic rupture/other injury
  - Aortic arch has much tighter radius of curvature
    - Increases risk of proximal attachment "bird beak"
  - Young patients also have smaller caliber aorta
    - Significant oversizing of endograft can cause poor graft apposition or infolding
    - Small-caliber endograft use may cause problems in later life as aortic diameter increases

Complications

- Most feared complication(s)
  - Spinal cord ischemia (3-6% incidence)
    - Intercostal arteries supply anterior spinal artery
      - ☐ Stent-graft covers intercostals
    - Less common than with open surgical repair (14%)
      - ☐ Increased risk with prior AAA repair, subclavian artery coverage, emergent repair, sustained hypotension
    - If noted early, treatment via CSF drainage (< 15 mL/h) & elevating systolic blood pressure > 160 mm Hg may reverse
  - Stroke (3-8% incidence)
    - TEVAR coverage of LSA
      - ☐ Utilizing LSA revascularization = 5.3%
      - ☐ Without LSA revascularization = 8.0%
    - Various causes
      - ☐ Catheter/device manipulation in diseased aorta; can dislodge plaque from arch, causing embolus
      - ☐ Proximity of endograft to great vessel origins; may serve as nidus for embolization/stroke
      - ☐ Posterior fossa/brainstem stroke from intentional LSA coverage during TEVAR
- Immediate/periprocedural complication(s)
  - **Intraprocedural complications**
    - Maldeployment of endograft
    - Aneurysm rupture, aortic dissection/perforation
      - ☐ Requires endograft extension intraprocedurally
      - ☐ If conversion to open repair required, balloon tamponade employed for hemostasis
  - **Other complications**
    - Myocardial infarction
      - ☐ 43% of perioperative deaths for aneurysm/dissection related to cardiac cause
    - Postimplantation syndrome: Transient leukocytosis, fever, elevated inflammatory markers
      - ☐ Possible endothelial activation by endograft
    - Reactive pleural effusion (37-73% incidence)
      - ☐ May be unilateral or bilateral
    - Access site complications
      - ☐ Hematoma, pseudoaneurysm, iatrogenic arteriovenous fistula formation, seroma
- Delayed complication(s)
  - **Endoleak**: Persistent perfusion of excluded aneurysm sac after endograft placement
    - **Type I**: Perfusion of aneurysm sac via ineffective seal at endograft attachment site
      - ☐ Most common TEVAR-associated endoleak
      - ☐ Almost always requires intervention
    - **Type II**: Perfusion of aneurysm sac via arterial branches arising from excluded aortic segment
      - ☐ Usually involves intercostal/bronchial arteries or intentionally covered LSA
      - ☐ Typically managed with observation
    - **Type III**: Perfusion of aneurysm sac due to mechanical problem with endograft (e.g., ineffective sealing/separation of overlapping graft components, rupture/tear of graft fabric)
      - ☐ Almost always requires intervention
    - **Type IV**: Perfusion of aneurysm sac due to graft fabric porosity; rarely seen with current endografts
      - ☐ Usually transient; managed with observation
    - **Type V**: Continued sac enlargement without identifiable endoleak; a.k.a. endotension
      - ☐ May represent endoleak that cannot be identified with available imaging techniques
  - Disease progression at endograft attachment zones
    - May lead to sac enlargement, endoleaks, rupture
  - Endograft device migration (> 10 mm)
    - Low migration potential in current devices (1-4%)
- Other complications
  - Very high morbidity/mortality to TAAA repair compared with TAA or AAA
    - Mortality ranges from 3-17%
      - ☐ 10% perioperative, 31% delayed mortality
    - Up to 11% spinal cord ischemia
    - Up to 15% of patients require hemodialysis

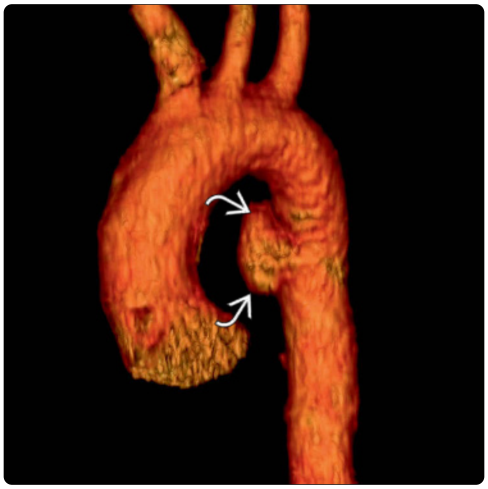
Expected Outcomes

- 95-98% technical success rate (uncomplicated TEVAR)
- Varied outcomes for thoracoabdominal aneurysms

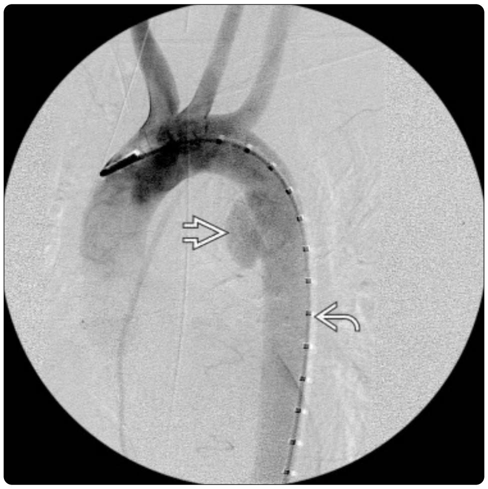
SELECTED REFERENCES

1. Abraha I et al: Thoracic stent graft versus surgery for thoracic aneurysm. Cochrane Database Syst Rev. CD006796, 2016

Acute Aortic Laceration (3D CTA)

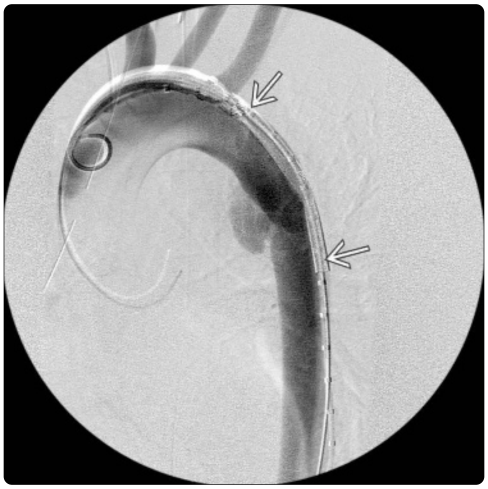


Acute Aortic Laceration (Thoracic DSA)

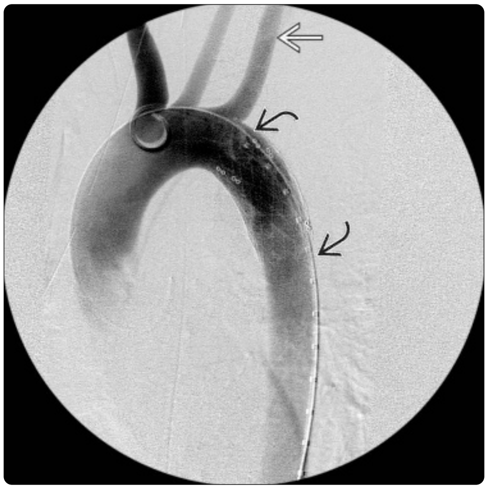


(Left) *A patient involved in a high-speed motor vehicle accident had multiple signs of trauma. A CECT 3D reformation shows a contained rupture (pseudoaneurysm) ↪ of the distal aortic arch. TEVAR is the preferred management of these injuries.* **(Right)** *The initial thoracic aortic DSA shows a calibrated pigtail catheter ↪ in the aorta with opacification of the great vessels and confirmation of the pseudoaneurysm ⇨. The injury location relative to the left subclavian artery origin affects endograft placement.*

Acute Aortic Laceration (Endovascular Repair of Injury)

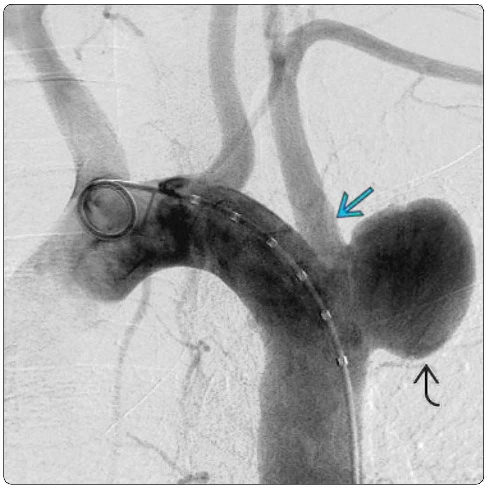


Acute Aortic Laceration (Post-TEVAR DSA)

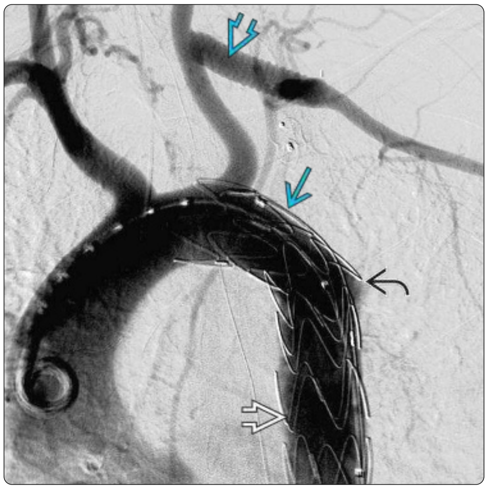


(Left) *DSA during endograft placement shows the device ⇨ contained within the delivery system has been positioned distal to the left subclavian artery origin.* **(Right)** *After TEVAR, the endograft ↪ has excluded the pseudoaneurysm while maintaining left subclavian artery ⇨ patency. Typically, a 2-cm proximal seal zone is needed to avoid a type I endoleak. This sometimes requires intentional coverage of the left subclavian artery and surgical bypass to reduce the risk of left arm or posterior fossa ischemia.*

TEVAR and Carotid-Subclavian Bypass Graft (Pretreatment)

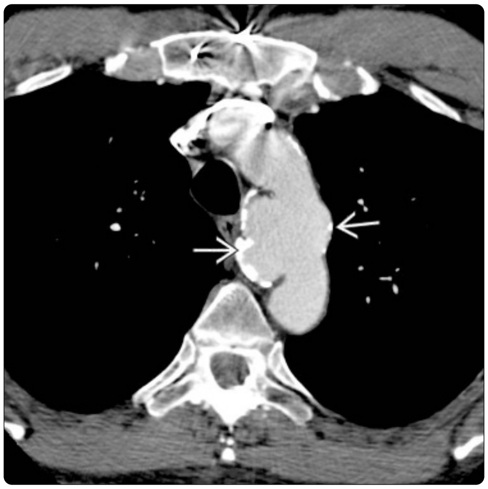


TEVAR and Carotid-Subclavian Bypass Graft (Posttreatment)

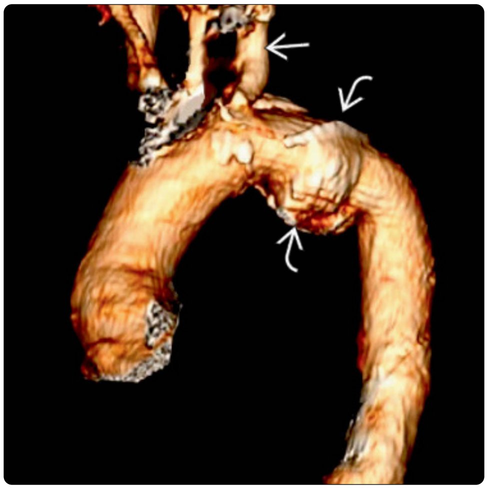


(Left) *A DSA shows a saccular aneurysm ↪ of the proximal descending thoracic aorta. TEVAR will require that the proximal attachment of the endograft cover the left subclavian artery ➡ because of the aneurysm proximity.* **(Right)** *Following TEVAR and left common carotid to left subclavian artery bypass, DSA shows that the left subclavian origin ➡ and saccular aneurysm are excluded ↪ by the endograft ⇨, and the distal subclavian artery fills via the newly created bypass shunt ⇛.*

(Left) *Axial CECT in a patient involved in an automobile accident 10 years prior & now with a chronic cough shows a calcified pseudoaneurysm* ➡ *of the aortic isthmus. A chronic pseudoaneurysm develops in 1-2% of cases of undiagnosed aortic injury.* **(Right)** *3D reformation shows a pseudoaneurysm* ↷ *& its proximity to the left subclavian artery* ➡*. Chronic aortic pseudoaneurysms may be asymptomatic or can enlarge & cause dysphagia, hoarseness, or cough. These are at risk for rupture & should be treated when identified.*

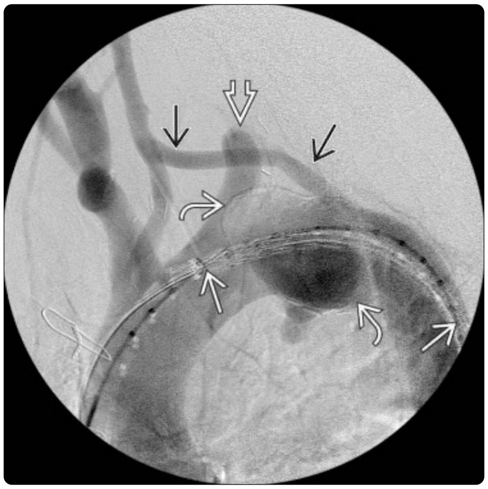


Pseudoaneurysm: Chronic Posttraumatic (Initial CTA)

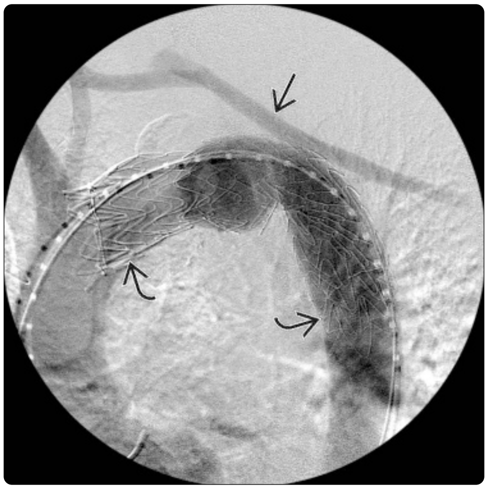


Pseudoaneurysm: Chronic Posttraumatic (3D CTA Reformation)

(Left) *A left carotid to left subclavian artery bypass* ⇨ *was performed prior to TEVAR, as it was felt that coverage of the left subclavian artery would be needed for an adequate proximal seal. DSA shows the endograft in the delivery system* ➡ *before deployment, the subclavian artery stump* ➡*, and the calcified pseudoaneurysm* ↷*.* **(Right)** *DSA after TEVAR shows no pseudoaneurysm opacification, c/w successful exclusion by the endograft* ↷*. The subclavian artery does not fill proximally but is perfused by the bypass distally* ⇨*.*

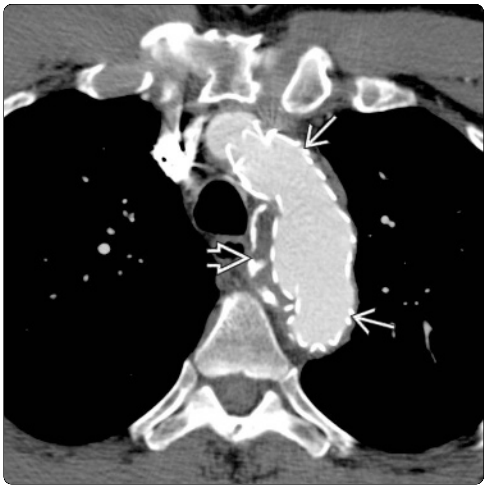


Pseudoaneurysm: Chronic Posttraumatic (TEVAR After Carotid-Subclavian Bypass)

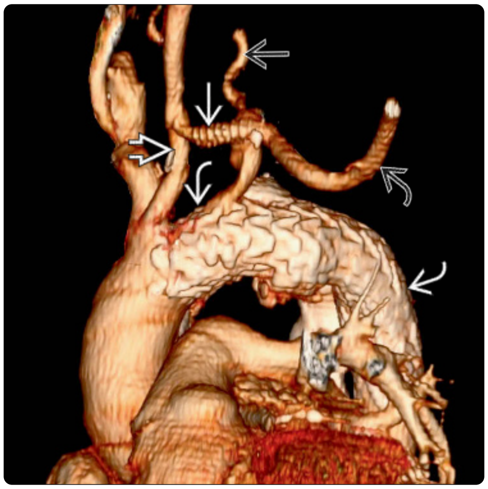


Pseudoaneurysm: Chronic Posttraumatic (DSA After TEVAR)

(Left) *Axial CTA obtained 1 month after TEVAR shows the opacified endograft* ➡ *within the transverse aorta. The calcified pseudoaneurysm* ➡ *can be seen, but there is no contrast identified within, demonstrating there is no endoleak and indicating successful exclusion.* **(Right)** *3D reformation demonstrates the post-TEVAR vascular anatomy. The endograft* ↷ *ends proximally adjacent to the left common carotid artery* ➡*, while the carotid-subclavian bypass* ➡ *fills both the vertebral* ⇨ *and distal left subclavian* ⇨ *arteries.*

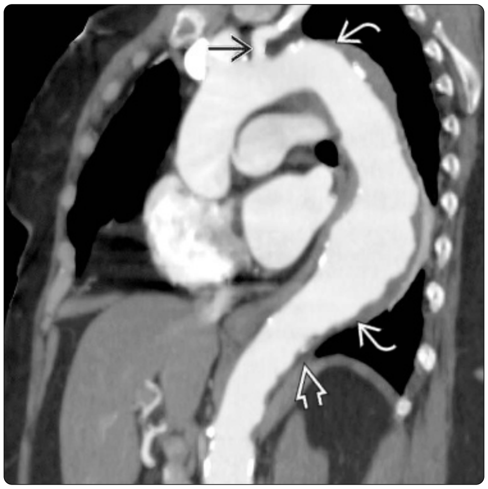


Pseudoaneurysm: Chronic Posttraumatic (Surveillance CTA)

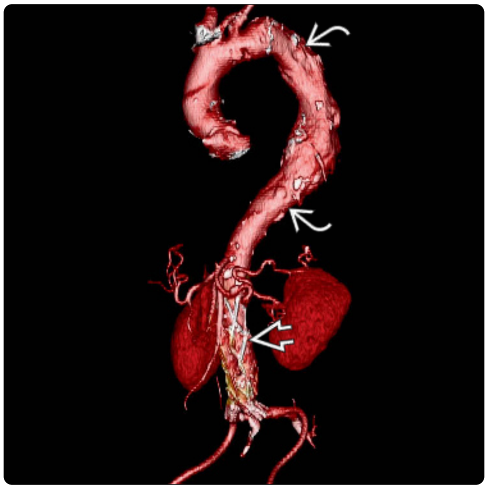


Pseudoaneurysm: Chronic Posttraumatic (Surveillance 3D Reformation)

Degenerative Thoracic Aortic Aneurysm (Initial CTA Imaging Evaluation)

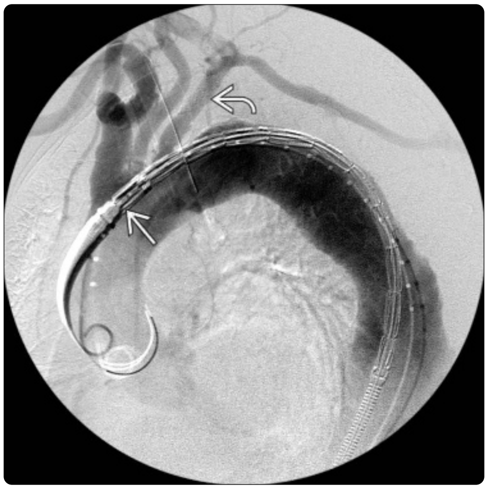


Degenerative Thoracic Aortic Aneurysm (Initial CTA Imaging Evaluation)

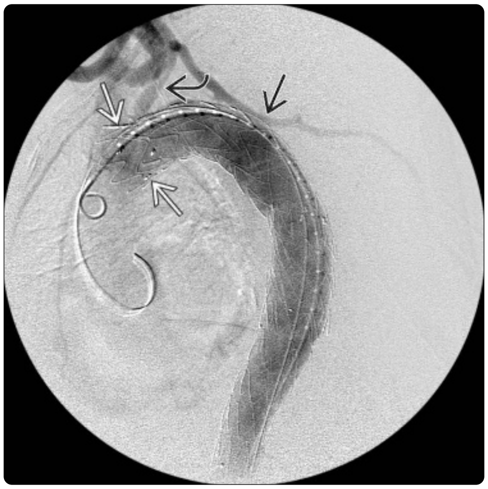


(Left) *CTA of the thoracic and upper abdominal aorta demonstrates a fusiform aneurysm* ↪ *of the distal arch and descending aorta. The aneurysm arises near the left subclavian artery* → *and terminates above the diaphragmatic hiatus* ⇨. **(Right)** *3D CTA reformation of the thoracoabdominal aorta shows an endograft* ⇨ *in the infrarenal aorta, indicating the patient had prior endovascular AAA repair. As the thoracic aneurysm* ↪ *does not involve the visceral segment of the abdominal aorta, this lessens the complexity of TEVAR.*

Degenerative Thoracic Aortic Aneurysm (Intraoperative DSA During TEVAR)

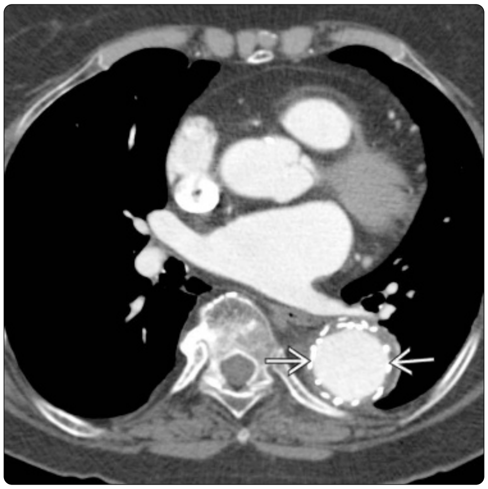


Degenerative Thoracic Aortic Aneurysm (Completion DSA After TEVAR)

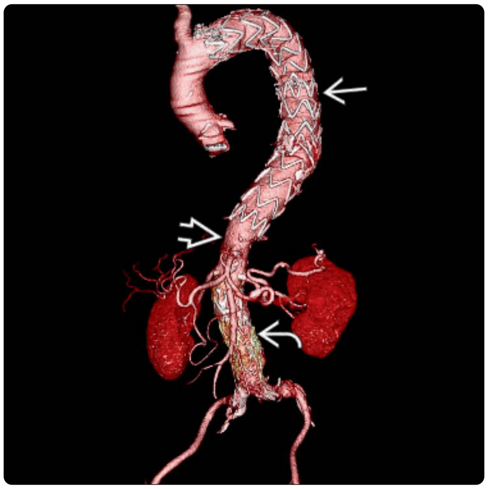


(Left) *Due to the aneurysm's proximity to the left subclavian artery, intentional coverage of the vessel was needed for adequate proximal seal. DSA during TEVAR shows the endograft* ⇨ *is positioned proximal to the subclavian artery* ↪. **(Right)** *DSA after endograft deployment shows the noncovered proximal stent* ⇨ *of the device extends across the left common carotid artery* ↪*, which remains patent. The distal left subclavian artery* → *is perfused via a carotid-subclavian artery bypass. (Courtesy C. Kwolek, MD.)*

Degenerative Thoracic Aortic Aneurysm (Surveillance CECT After TEVAR)



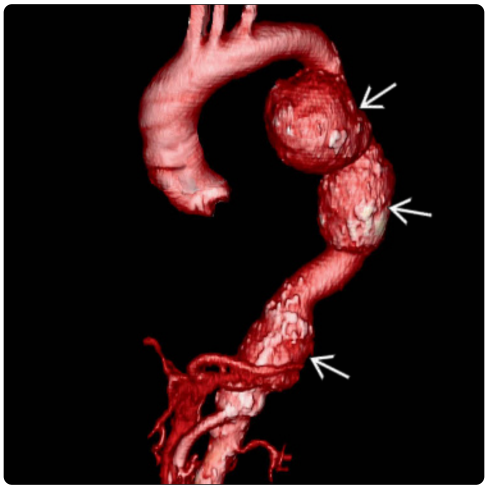
Degenerative Thoracic Aortic Aneurysm (Surveillance CTA After TEVAR)



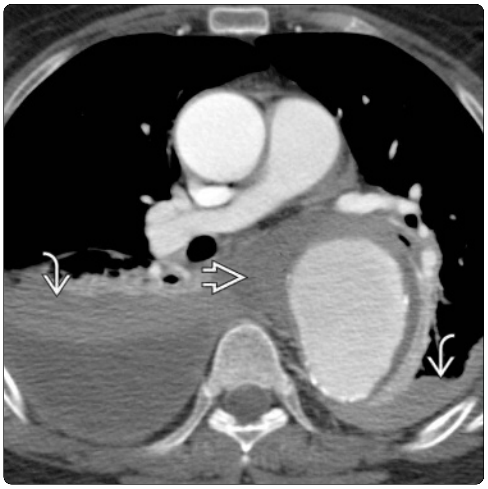
(Left) *Post-TEVAR surveillance imaging for delayed complications is mandatory. CECT 1 month after TEVAR shows the endograft* ⇨ *in the descending aorta. Images should be carefully evaluated for endoleak, as these are the most frequent delayed complication. If a type I or III endoleak is seen, intervention is almost always required due to the high rupture risk.* **(Right)** *3D CTA reformation shows both the thoracic* ⇨ *and abdominal aortic* ↪ *endografts in place with a normal-caliber aorta* ⇨ *between the devices.*

(Left) *Sagittal 3D reformation in a hypotensive patient with acute back pain reveals a complex thoracoabdominal aortic aneurysm, which has 3 distinct saccular components ➔. The lowest component extends to the visceral segment of the abdominal aorta.* **(Right)** *A contained aneurysmal rupture ⇨ is the etiology for the back pain. Bilateral hemothoraces ↪ are present. The patient was stabilized. Controlled hypotension is preferred to avoid exacerbating the contained rupture.*

Emergent TEVAR: Thoracoabdominal Aortic Aneurysm (3D CTA)

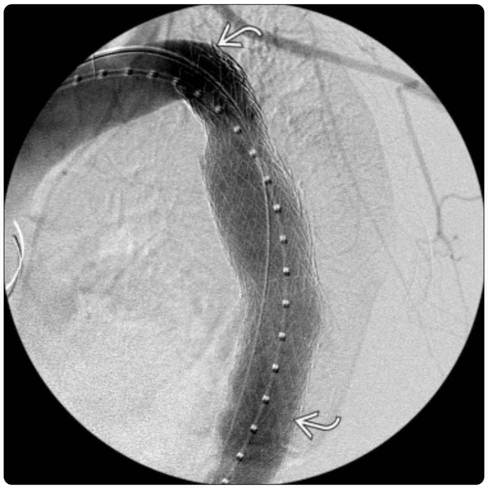


Emergent TEVAR: Thoracoabdominal Aortic Aneurysm (Contained Rupture)

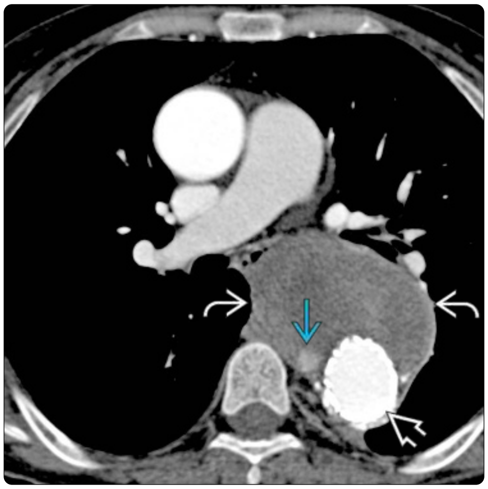


(Left) *Overlapping sequential endografts ↪ excluded the contained rupture, proximally located within the descending thoracic aneurysm. The lowest component of aneurysm was not excluded due to the visceral artery involvement.* **(Right)** *Surveillance CECT 6 months after TEVAR shows the endograft ⇨ within a large residual aneurysm sac ↪ that has continued to expand. Focal contrast within the aneurysm sac and outside of the endograft represents a type II endoleak ➡ that continues to pressurize and thus expand the sac.*

Emergent TEVAR: Thoracoabdominal Aortic Aneurysm (Endograft Placement)

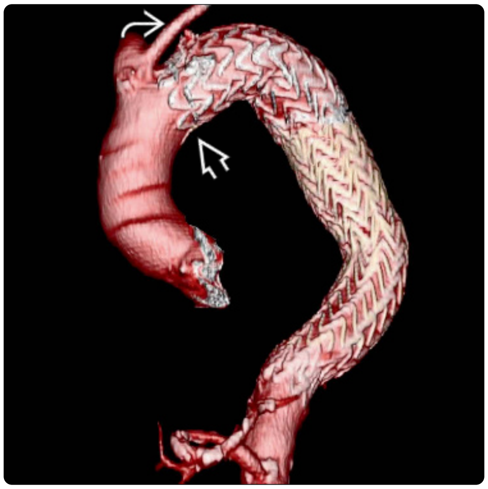


Emergent TEVAR: Thoracoabdominal Aortic Aneurysm (Type II Endoleak)

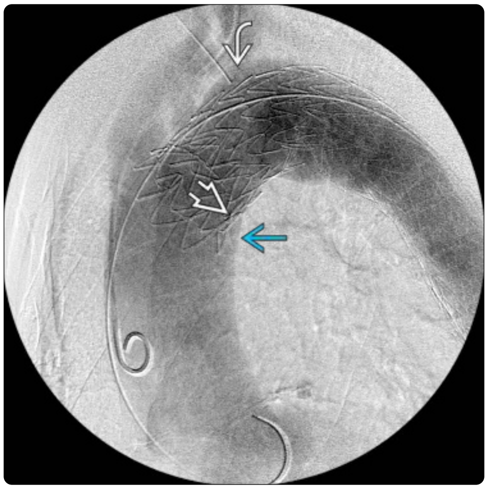


(Left) *A different patient who underwent TEVAR for a descending thoracic aortic aneurysm shows that the proximal endograft margin ⇨ extends to the left common carotid artery ↪. The left subclavian artery was intentionally covered by the endograft.* **(Right)** *Incomplete apposition of the endograft undersurface ⇨ to the aortic wall lesser curvature, causes a wedge-shaped gap known as a "bird beak" ➡. This is a risk factor for proximal endograft collapse and also increases the risk of a type I endoleak ↪, as seen in this case.*

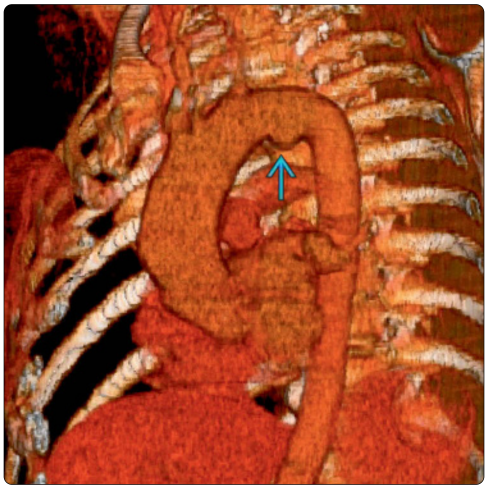
"Bird-Beak" Endograft: Increased Risk of Endoleak (CECT 3D Reformation)



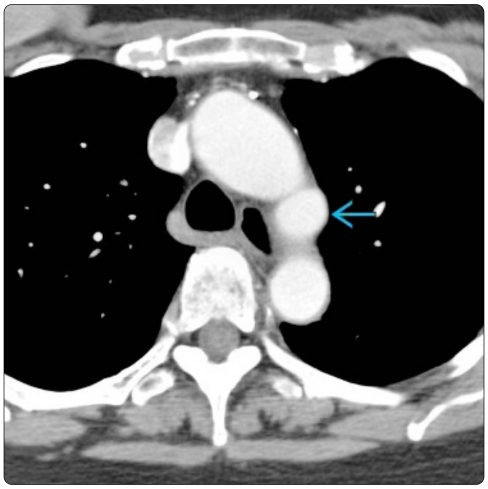
"Bird-Beak" Endograft: Increased Risk of Endoleak (DSA)



Benign Mimic of Injury: Ductus Diverticulum (Oblique CECT 3D Reformation)

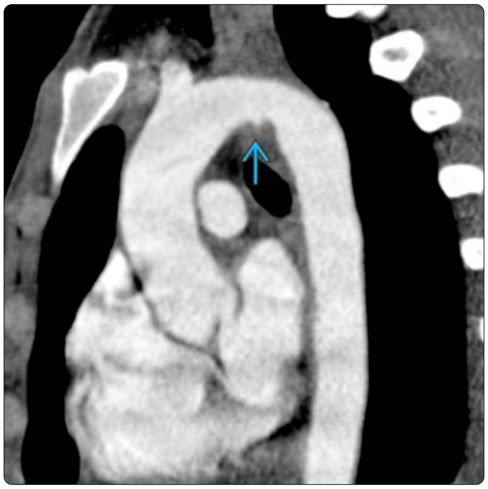


Benign Mimic of Injury: Ductus Diverticulum (CECT)

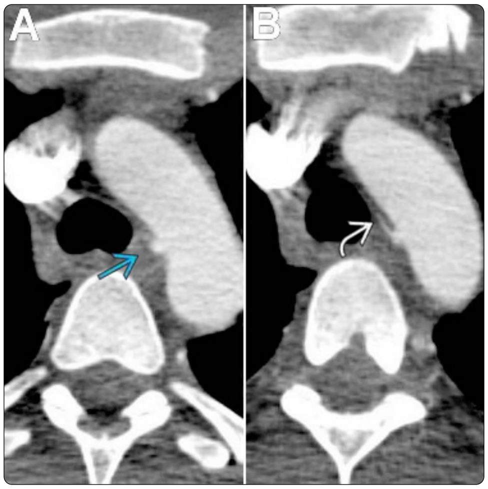


(Left) *A smoothly marginated focal bulge* → *is seen along the inferomedial aspect of the lesser curve of thoracic aortic arch. This is the typical location & appearance of a ductus diverticulum, a benign finding seen in 9% of adults. In the setting of trauma, this can potentially be confused with a traumatic aortic injury.* **(Right)** *This axial CECT also demonstrates the smooth margins of a benign ductus diverticulum* → *focally projecting from the aortic isthmus. The aortic wall of the diverticulum is intact, & there is no mediastinal hematoma.*

Benign Mimic of Injury: Aortic Branch Vessel Infundibulum (Sagittal CECT)

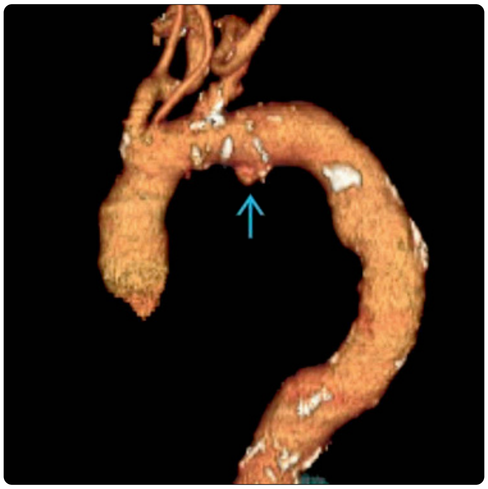


Benign Mimic of Injury: Aortic Branch Vessel Infundibulum (Axial CECT)

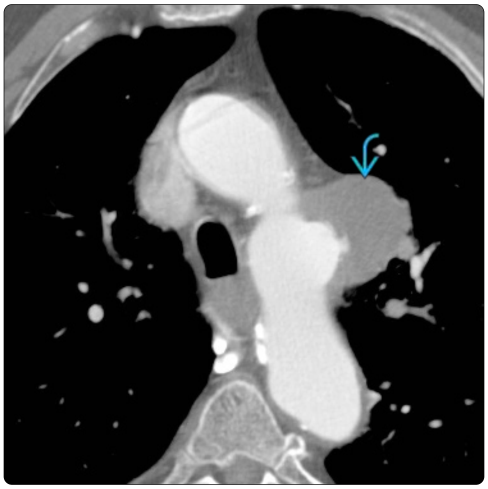


(Left) *A small contrast collection* → *projects inferomedially from the aortic isthmus in a patient involved in an automobile accident. This was initially felt to represent an acute aortic injury.* **(Right)** *Axial CECT centered at the collection seen on the sagittal image shows (A) a well-defined round focus* → *projecting inferomedially. (B) A slightly more cephalad image shows that a small bronchial artery* ➦ *extends from the contrast focus (i.e., conical arterial infundibulum) toward the airway.*

Ductus Diverticulum: Aneurysmal Enlargement (3D CECT Reformation)



Ductus Diverticulum: Aneurysmal Enlargement (Thoracic CECT)



(Left) *Although a ductus diverticulum is usually a benign entity, it can rarely become aneurysmal in adults. The aneurysm can erode into the airway, esophagus, pericardium, or pleural cavity with severe consequences. A 3D sagittal reformation shows an enlarged, irregular ductus diverticulum* →*.* **(Right)** *This partially thrombosed ductus diverticulum aneurysm* ↷ *can be at risk of rupture, particularly once the diameter exceeds 3 cm. These typically can be managed effectively with TEVAR.*

Endoleak Repair

KEY FACTS

TERMINOLOGY

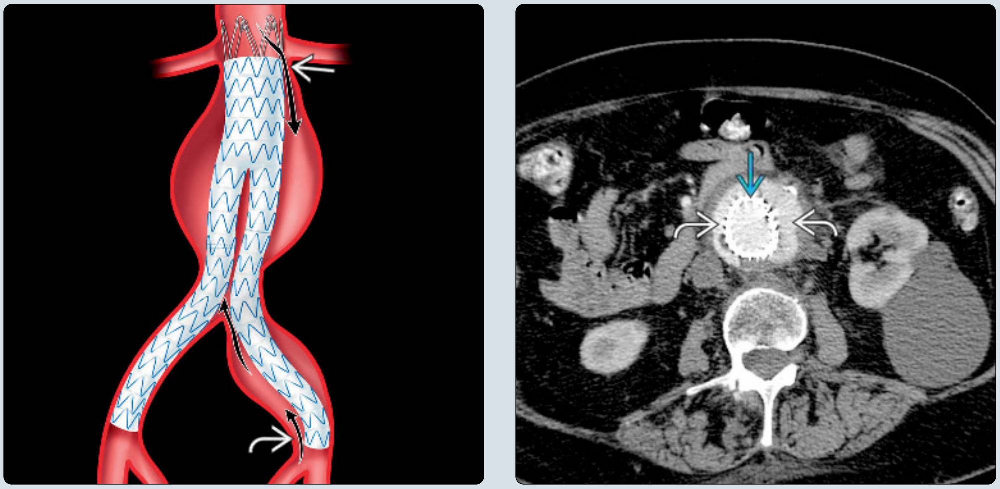
- **Endoleak**: Persistent perfusion of excluded aneurysm sac after endograft placement
  - **Type I**: Perfusion of aneurysm sac via incomplete/ineffective seal at endograft attachment site
  - **Type II**: Perfusion of aneurysm sac via arterial branches arising from excluded aortic segment
  - **Type III**: Perfusion of aneurysm sac due to mechanical problem with endograft
  - **Type IV**: Perfusion of aneurysm sac due to graft fabric porosity; rarely seen with current endografts
  - **Type V**: Continued sac enlargement without identifiable endoleak; a.k.a. endotension

PROCEDURE

- Type IA endoleak repair
  - Attempt additional expansion of endograft using large-diameter compliant balloon
  - Place high radial force bare metal stent if compliant balloon fails to seal endoleak
  - Or place covered overlapping aortic extension cuff
- Type IB endoleak repair
  - Poor endograft limb apposition at distal attachment
  - Requires additional endograft limb extension into external iliac artery to achieve distal seal
- Type II endoleak repair
  - Effective transarterial repair requires embolization via catheter placed directly into endoleak nidus
  - Must eliminate nidus and inflow/outflow vessels
- Type III endoleak repair
  - May need to place additional endograft component

POST PROCEDURE

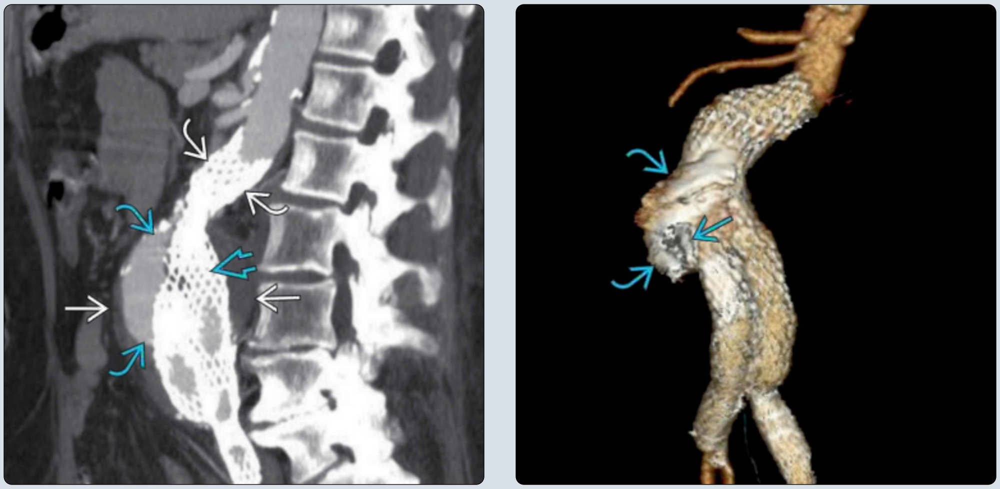
- > 90% success rate reported in treating type II endoleaks via translumbar route
- 80% recurrence rate if treated transarterially unless sac entered and nidus embolized



Type I Endoleak Repair

Type I Endoleak Repair

(Left) *Type I endoleaks involve the attachment sites of the endograft to the native artery. If an endoleak occurs at the proximal attachment site ➡, it is termed IA endoleak, whereas distal attachment site ➦ involvement is known as IB endoleak.* **(Right)** *Arterial phase CECT demonstrates a very large type IA endoleak. Contrast ➦ surrounds the endograft ⇨ just below the proximal attachment within the infrarenal abdominal aortic aneurysm (AAA) neck. There is a high risk of aneurysm rupture unless this type of endoleak is repaired.*



Type I Endoleak Repair

Type I Endoleak Repair

(Left) *Sagittal reformation again demonstrates the very large type IA endoleak. A large contrast collection ↪ is seen extending anteriorly and inferiorly within the AAA sac ➡ adjacent to the endograft ⇨. Although superiorly the endograft appears to be apposed to the aortic wall ➦, there is an endoleak.* **(Right)** *Type I endoleak was treated using a combination of cyanoacrylate (glue) ↪ and coils ⇨ to eliminate the endoleak by creating a satisfactory seal just below the proximal attachment of the endograft.*

TERMINOLOGY

Definitions

- **Endoleak**: Persistent perfusion of excluded aneurysm sac after endograft placement
  - **Type I**: Perfusion of aneurysm sac via incomplete/ineffective seal at endograft attachment site
    - Type IA: Originates at proximal attachment site
      - e.g., infrarenal attachment of upper margin of bifurcated abdominal aortic endograft body
    - Type IB: Originates at distal attachment site
      - e.g., common iliac artery attachment of limb of bifurcated abdominal aortic endograft
  - **Type II**: Perfusion of aneurysm sac via arterial branches arising from excluded aortic segment
    - Similar pathophysiology to arteriovenous malformation
      - Patent arterial side branches continue to perfuse residual abdominal aortic aneurysm (AAA) sac
      - Endoleak within AAA sac acts as nidus; endoleak repair requires elimination of nidus
    - Most common endoleak type
  - **Type III**: Perfusion of aneurysm sac due to mechanical problem with endograft
    - e.g., ineffective sealing/separation of overlapping graft components, rupture/tear of graft fabric
  - **Type IV**: Perfusion of aneurysm sac due to graft fabric porosity; rarely seen with current endografts
    - Usually transient; may be related to aggressive intraprocedural anticoagulation
  - **Type V**: Continued sac enlargement without identifiable endoleak; a.k.a. endotension
    - May represent endoleak that cannot be identified

Expectant Management of Endoleaks

- **Type I endoleak**
  - Cannot be managed conservatively
    - Represents direct communication with systemic blood flow; high risk of rupture if untreated
      - Invariably requires intervention
- **Type II endoleak**
  - Optimal management remains controversial
    - Some investigators advocate immediate repair
    - Other investigators recommend expectant management until aneurysm shows enlargement
      - 17% show enlargement if early type II endoleak
      - 55% of aneurysms show enlargement with persistent (≥ 6 months) type II endoleak
  - Typically has relatively benign course
    - Many seal spontaneously over time; conservative management usually justified
      - 14-25% incidence after endovascular aneurysm repair (EVAR) at 1 month; 10.2% after 1 year
- **Type III endoleak**
  - Cannot be managed conservatively
    - Endograft defect or separation of components reperfuses aneurysm sac with systemic blood
      - Invariably requires intervention
- **Type IV endoleak**
  - Managed conservatively; occurs infrequently
  - Much less frequent with current endograft technology; improved fabrics
- **Type V endoleak**
  - Usually managed conservatively/observed
  - May require intervention if continued sac enlargement, despite lack of endoleak on imaging

PREPROCEDURE

Indications

- **Type I endoleak**
  - Should always be repaired when identified
    - If noted during EVAR or thoracic endovascular aortic repair (TEVAR), should be treated at that time
    - Should also treat any delayed type I endoleak seen on surveillance imaging
      - May occur with device migration
- **Type II endoleak**
  - Despite management controversies, all investigators agree that any persistent type II endoleak with AAA sac enlargement must be repaired
- **Type III endoleak**
  - Should always be repaired when identified
- **Types IV and V endoleaks**
  - Enlarging residual AAA sac may require intervention

Contraindications

- **Relative contraindications**
  - History of severe contrast allergy/anaphylaxis
  - Severe renal insufficiency
    - Nondialysis dependent
    - May consider alternative contrast agent (e.g., CO_2)
  - Uncorrectable coagulopathy
  - Persistent but stable type II endoleak
    - No AAA sac enlargement despite endoleak
      - Continued surveillance imaging mandatory
    - Appropriate management remains controversial
- **No absolute contraindications**

Preprocedure Imaging

- CTA
  - Standard post-EVAR/TEVAR surveillance imaging
    - Accurately detects presence of endoleak
      - Requires initial NECT; shows calcifications that could be mistaken for endoleak on CECT
      - Requires CECT in arterial and delayed phases
    - Sometimes difficult to determine endoleak type
- MRA
  - Very sensitive for endoleak detection
    - Limited by metallic artifact from certain endografts
  - Time-resolved MRA can give real-time information regarding endoleaks; differentiates endoleak types
    - Noncontrast sequences, such as "white blood" imaging, also available

Getting Started

- Things to check
  - Clinical history and physical examination
    - Current medications
      - Any anticoagulants, antiplatelet agents, oral hypoglycemic agents, antihypertensives

  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60
    - Complete blood count
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ratio ≤ 1.5
- Medications
  - Agents for moderate sedation
    - Fentanyl
    - Midazolam
  - Heparin
    - Various intraprocedural administration regimens
      - Bolus dose of 2,500-5,000 U; followed by infusion of 1,000 U/h
      - Loading dose of 50-100 U/kg; followed by continuous infusion of 15-25 U/kg/h
  - Vasodilator
    - Typical bolus dose of 100 μg of nitroglycerin
    - Prevents/treats catheter-induced vasospasm
- Equipment list
  - Access needle for translumbar puncture
    - 19-g trocar needle (20 cm in length)
      - Used in combination with vascular access sheath
    - 19-g sheathed trocar needle (20 cm in length)
      - Alternative needle choice
  - Access sheaths
    - 5- to 8-Fr vascular access sheath
      - May be used for arterial or translumbar access
    - Large-caliber access sheath (e.g., 9-24 Fr)
      - Used for compliant balloon, large-diameter stents, additional endograft components
  - Catheters
    - Calibrated ("marker") flush catheter
      - e.g., pigtail, Omni Flush catheter
    - Selective catheter (e.g., Davis, Simmons)
      - Hydrophilic straight/angled catheter
      - May be used to direct guidewire into target artery
    - Coaxial 2.6- to 3.0-Fr microcatheter
      - Various proprietary options
    - Large compliant balloon to distend endograft
      - Coda balloon (Cook; Bloomington, IN)
      - Reliant balloon (Medtronic; Minneapolis, MN)
  - Guidewires
    - Initial "starting" 0.035" guidewire
    - Angled or straight-tipped hydrophilic guidewire
      - Useful for selective catheterization
    - Stiff guidewire (e.g., Amplatz, Lunderquist)
      - Stability when advancing/placing devices
    - 0.014"-0.018" microwire
      - For use with microcatheter
  - Embolic agents
    - Coils
      - Detachable 0.035" or 0.018" embolization coils
      - "Pushable" 0.035" or 0.018" embolization coils
    - Liquids
      - N-butyl cyanoacrylate Trufill (Cordis; Bridgewater, NJ)
      - Onyx (ev3 Neurovascular; Irvine, CA)
      - Thrombin: Activates coagulation cascade
    - Plug occluding device
      - Amplatzer plug (St. Jude Medical; St. Paul, MN)
  - Stents
    - Large-caliber high radial force stent, e.g., Palmaz XL (Cordis; Miami Lakes, FL)
      - Must be mounted on balloon for deployment
      - Used to treat type IA endoleak
  - **Endograft converters/extensions**
    - Endologix AFX extension (Endologix; Irvine, CA): Extends proximal body of in situ endograft
      - Suprarenal or infrarenal fixation; 25-32 mm in diameter
    - Endurant aortic extension (Medtronic): Extends proximal body of in situ endograft
      - Suprarenal fixation; 23-36 mm in diameter
    - Gore Excluder extender (WL Gore; Flagstaff, AZ): Extends proximal body of in situ endograft
      - Infrarenal fixation; 23-32 mm in diameter
    - Zenith Renu converter (Cook): Converts in situ endograft to aorto-uni-iliac endograft
      - Suprarenal fixation; 22-36 mm in proximal diameter, tapers to 12 mm in distal diameter
    - Zenith Renu main body extension (Cook): Extends proximal body of in situ endograft
      - Suprarenal fixation; 22-36 mm in diameter
  - **Endostaples**
    - Anchoring system designed to enhance proximal endograft fixation and sealing at AAA neck; may be used during initial EVAR or for type I endoleak repair
      - Aptus Heli-FX EndoAnchor System (Medtronic): Metallic screw-like anchors used to "staple" endograft to aorta; simulates surgical anastomosis
      - Contraindicated with excessive calcification or thrombus in attachment zone
  - Closure devices
    - Placed during percutaneous access for endoleak repair; allows suture-mediated closure/hemostasis
      - ProStar XL (Abbott Vascular; Abbott Park, IL)
      - Perclose ProGlide (Abbott Vascular)

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Common femoral artery access used for some repairs
    - May require large-caliber access sheath/device
      - If additional endograft components used for endoleak repair, need adequate arterial diameter
      - Access via surgical femoral arteriotomy or via percutaneous access using "preclose" technique
    - Some endoleaks repaired via 5- to 8-Fr access
      - If selective angiographic catheter adequate for repair; may also use brachial artery access
  - Translumbar puncture of residual AAA sac sometimes required as access for type II endoleak repair
    - Patient positioned prone
      - Fluoroscopic guidance usually used during access
      - CT guidance rarely used during access

Procedure Steps

- **Type I endoleak repair**
  - **General**
    - Consider arterial access via 2 separate access sites
      - For flush catheter and for device introduction
    - Introduce flush catheter via contralateral access site
    - Position catheter sideholes at endoleak level
    - Inject contrast via flush catheter; obtain DSA
      - Analyze images for relationship of endoleak to endograft and cerebral/renal arteries; determine most appropriate endovascular treatment
    - Use contralateral access for endoleak repair
      - Allows DSA via flush catheter during repair
  - **Inadequate endograft apposition to aorta**
    - Attempt additional expansion of endograft using large-diameter compliant balloon
    - Place high radial force bare metal stent if compliant balloon fails to seal endoleak
      - Palmaz XL balloon-mounted stent usually used
    - Stent should span proximal endograft attachment
      - Should extend from below endograft fabric into suprarenal aorta; reinforces suprarenal fixation
    - Some investigators have used endostaples to enhance proximal endograft attachment
  - **Device migration/low endograft placement**
    - Place covered overlapping aortic extension cuff (e.g., Zenith Renu main body extension)
      - Need sufficient native aorta between cerebral/renal arteries and fabric of endograft for cuff placement without covering critical arteries
      - Extremely precise positioning mandatory
      - Distend new attachment site and overlapping endograft-cuff junction with compliant balloon
    - Alternatively, use Zenith Renu converter
      - Proximal aortic cuff with suprarenal fixation; extends above in situ endograft, seals endoleak
      - Cuff tapers distally into smaller diameter; can be placed in iliac limb of in situ endograft
      - Creates aorto-uni-iliac endograft; contralateral iliac occluder and femoro-femoral bypass needed
    - May sometimes require fenestrated proximal aortic cuff or use of parallel graft ("snorkel or chimney") extensions to paravisceral aorta
  - **Type IB endoleak repair**
    - Due to inadequate apposition of endograft limb at distal attachment (typically common iliac artery)
      - Requires additional endograft limb extension into external iliac artery to achieve distal seal
    - Prior to extending limb into external iliac, must embolize internal iliac artery; prevents retrograde perfusion of common iliac artery
      - Place embolization coils proximally; transpelvic collateralization minimizes buttock claudication
    - After internal iliac artery embolization, extend overlapping iliac limb into external iliac artery
      - Distend overlap with compliant balloon
- **Type II endoleak repair**
  - **Transarterial endoleak repair**
    - Place patient supine on fluoroscopy table
    - Sterilely prepare/drape intended arterial access site
      - Usually femoral, sometimes brachial access
    - Obtain arterial access; place sheath
    - Place selective catheter into artery supplying endoleak; various possible target arteries
      - Superior mesenteric artery (SMA) may perfuse inferior mesenteric artery (IMA)
      - Internal iliac arteries may perfuse lumbar arteries
    - Obtain DSA after catheterizing target artery
    - Review images to confirm direct communication between target artery and endoleak
      - Potential pathways from SMA to IMA via arc of Riolan/marginal artery of Drummond
      - Potential pathway from internal iliac to lumbar arteries via iliolumbar arteries
    - May be able to access endoleak if pathway present
    - Effective transarterial repair requires embolization via catheter placed directly into endoleak nidus
      - Embolization of only feeding vessels ineffective; endoleak will recruit additional inflow
    - Introduce coaxial microcatheter; negotiate into endoleak nidus within AAA sac
    - Embolize endoleak using chosen embolic agent(s)
      - Must eliminate nidus and inflow/outflow vessels
  - **Translumbar endoleak repair**
    - Place patient prone on fluoroscopy table
    - Sterilely prepare/drape left or right paralumbar area
      - AAA usually projects to left; typically better access to residual AAA sac via left-sided approach
      - May occasionally access from right (e.g., large AAA with right-sided endoleak on imaging)
      - Right-sided access may require inferior vena cava puncture to reach AAA sac; shown to have no sequelae
    - Anesthetize planned skin entry point
      - ~ 4-5 finger breaths from posterior midline, measured from vertebral spinous process
    - Make small dermatotome at planned entry point
    - Introduce 19-g trocar needle via dermatotome
    - Direct needle anteromedially toward AAA sac
      - Needle should pass adjacent to vertebra
    - Adjust needle if vertebral body contacted
      - Angle slightly anterolaterally to enter AAA
    - Advance needle into AAA sac; avoid endograft
      - Should feel needle penetrate aortic wall
    - Remove stylet from needle
      - Should have brisk flow through needle/sheath; may not be pulsatile
      - If no blood flow, reposition needle
    - May introduce guidewire and place access sheath if using nonsheathed needle
      - May place selective catheter/microcatheter via sheath; direct catheter into endoleak if necessary
    - Inject contrast via sheath/catheter; obtain DSA
      - Determine size/extent/anatomy of endoleak
      - Demonstrate inflow/outflow vessels
    - Embolize endoleak using chosen embolic agent(s)
      - Must eliminate nidus and inflow/outflow vessels
- **Type III endoleak repair**
  - May need to place additional endograft component

    - Separation of modular endograft components managed by placing bridging endograft
    - Disrupted fabric managed by relining defective endograft segment with new component

Alternative Procedures/Therapies

- Surgical
  - Open surgical conversion/endograft resection
    - Reserved for large endoleaks unresponsive to endovascular repair
  - AAA sacotomy and removal of intrasac thrombus; concurrent ligation of IMA and lumbar arteries
    - Alternative to surgical endograft removal
  - Laparoscopic retroperitoneal ligation
    - Surgical ligation/clipping of inferior mesenteric and lumbar arteries supplying type II endoleak
- Endoleak prevention prophylaxis
  - Some investigators advocate "prophylaxis" prior, during or after EVAR for endoleak prevention or incidence reduction
    - Coil embolization of aortic side branches to prevent type II endoleak
    - Deployment of polymer surrounding endograft flow lumina during EVAR (investigational)
      - Nellix EndoVascular Aneurysm Sealing system (Endologix): Designed to seal AAA sac space, potentially reduce persistent sac flow/endoleaks
  - Data that post-EVAR warfarin use increases endoleak incidence
    - Specifically increased risk of type II endoleak
      - Also contributes to persistent AAA sac expansion

POST PROCEDURE

Things To Do

- **Postprocedure clinical follow-up**
  - Should continue to follow patient clinically
    - Ongoing assessment for any EVAR-related delayed complications
      - This includes monitoring for complications that may occur in addition to recurrent endoleak
- **Postprocedure imaging**
  - Must continue post-EVAR surveillance imaging
    - Delayed endoleaks well-recognized entity
      - Must monitor for endoleak recurrence
      - New or existing endoleak associated with AAA sac enlargement may eventually require repair

OUTCOMES

Complications

- Immediate/periprocedural complication(s)
  - Access site complications (1-10% incidence)
    - Hematoma/pseudoaneurysm/iatrogenic arteriovenous fistula formation/seroma
  - Unintentional renal artery coverage by proximal aortic extension component during endoleak repair
    - May require stenting or surgical bypass
  - Unintentional mesenteric artery coverage by proximal aortic extension component during endoleak repair
    - Much less common than unintentional renal artery coverage by proximal aortic extension component
    - May require stenting or surgical bypass
      - If untreated, could lead to bowel ischemia
  - Displacement of atheroma/thrombus into critical aortic side branch during placement of conversion component
    - May compromise renal or mesenteric perfusion
    - May require surgical/endovascular intervention
  - Nontarget embolization
    - Embolization agent(s) could be unintentionally deployed into critical vascular territories
      - Onyx, coils, or glue may migrate during deployment
  - Contrast-induced nephropathy
- Delayed complication(s)
  - Buttock claudication
    - Associated with internal iliac artery embolization
      - Erectile dysfunction reported in up to 17%
      - Gluteal necrosis, colonic ischemia also reported

Expected Outcomes

- Endoleak resolution on postprocedure imaging
  - > 90% success rate reported in treating type II endoleaks via translumbar route
  - 80% recurrence rate for type II endoleaks treated transarterially unless sac entered and nidus embolized
    - Comparable success to translumbar treatment if nidus and inflow/outflow vessels treated

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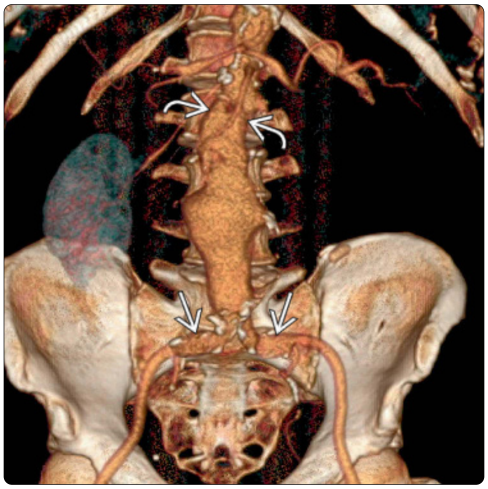
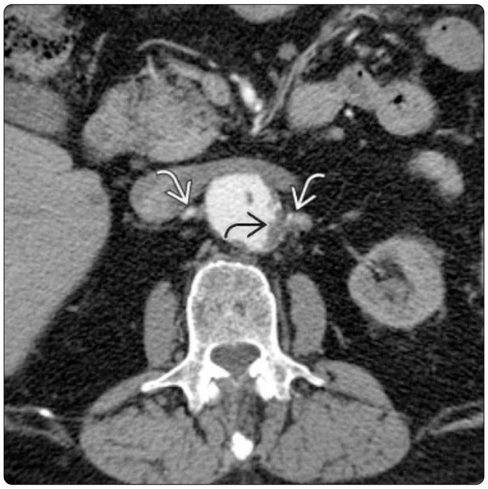
Stenting of Type IA Endoleak: Initial Evaluation With CTA

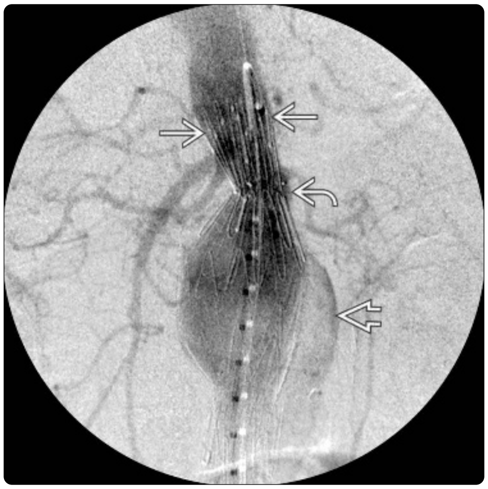


Stenting of Type IA Endoleak: Initial Evaluation With CECT

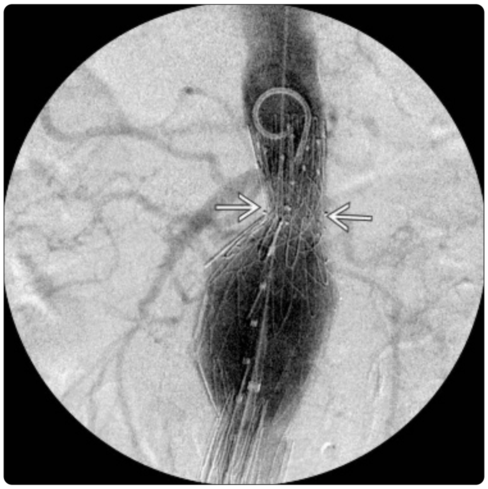


(Left) *Coronal 3D CTA reformation shows a fusiform AAA with conical shape to the infrarenal neck* ↷*. Although common iliac arteries* ➔ *are calcified and have a transverse orientation, the overall quality of the access arteries is satisfactory for endovascular aneurysm repair (EVAR).* **(Right)** *Axial CECT of the aneurysm neck slightly below the renal arteries* ↷ *shows eccentric mural thrombus* ⇨ *in the aortic lumen. A conical thrombus-containing neck at the proximal endograft attachment is a known risk factor for type IA endoleak.*

Stenting of Type IA Endoleak: Intraprocedural Endoleak on DSA

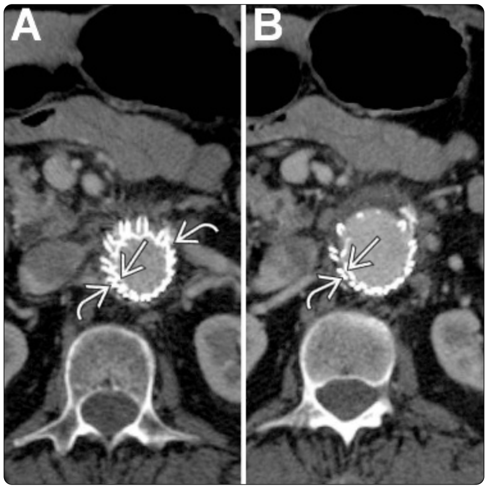


Stenting of Type IA Endoleak: Endoleak Repair With Palmaz Stent

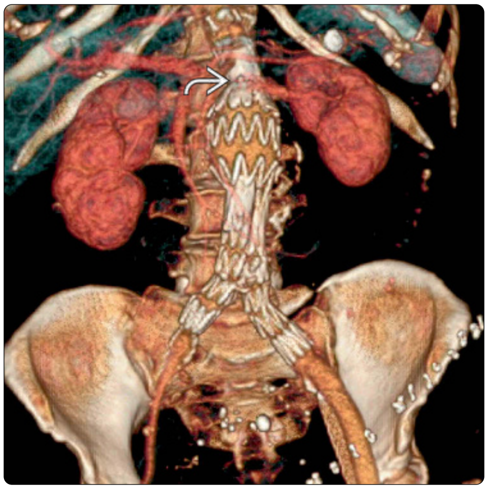


(Left) *DSA during EVAR shows an endograft in place. While the endograft conforms to the conical neck & the suprarenal stent* ➔ *anchors the device appropriately, contrast* ⇨ *fills the AAA sac, indicating a type I endoleak. Incomplete endograft apposition* ↷ *to the aorta can be seen adjacent to the left renal artery.* **(Right)** *A balloon-mounted Palmaz stent was deployed within the endograft, spanning the infrarenal neck & suprarenal aorta. This high radial force stent further expanded* ➔ *the endograft, eliminating the type IA endoleak.*

Stenting of Type IA Endoleak: Post-EVAR Surveillance CECT



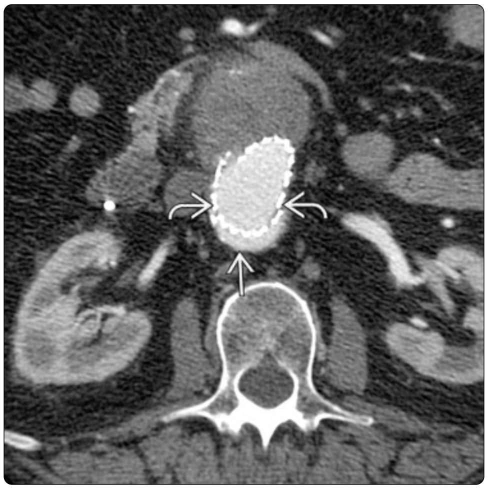
Stenting of Type IA Endoleak: Post-EVAR Surveillance CTA



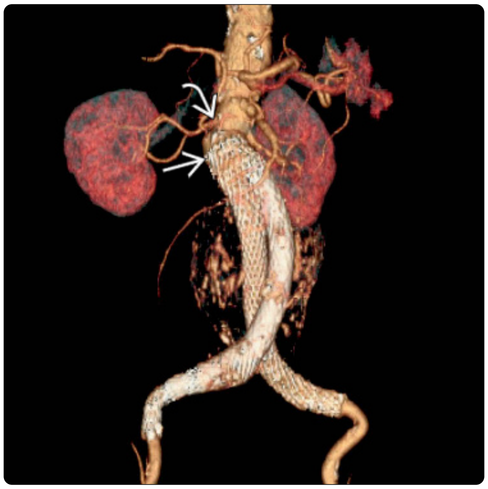
(Left) *Axial post-EVAR surveillance CECT at (A) suprarenal & (B) infrarenal levels shows the Palmaz stent* ➔ *within the metallic stents* ↷ *of the endograft with very close apposition of the 2 stents. More caudal axial images failed to demonstrate an endoleak. Placement of a high radial force stent is often useful in eliminating a type IA endoleak caused by poor endograft contact with the aortic wall.* **(Right)** *Post-EVAR CTA shows the configuration of the endograft. Despite the conical neck* ↷*, the endograft appears well positioned.*

(Left) *CECT in a patient who underwent EVAR 1 year prior shows contrast → between the endograft ↪ & posterior aortic wall. Caudally, there was interval enlargement of the residual AAA sac. When compared to the initial post-EVAR CECT, proximal margin of the endograft was now located more inferiorly. The findings are consistent with type IA endoleak from distal endograft migration.* **(Right)** *3D CTA reformation shows that the proximal edge → of the endograft lies below the right renal artery ↪ & does not attach within the neck.*

Type IA Endoleak From Migration: Initial Evaluation With CECT

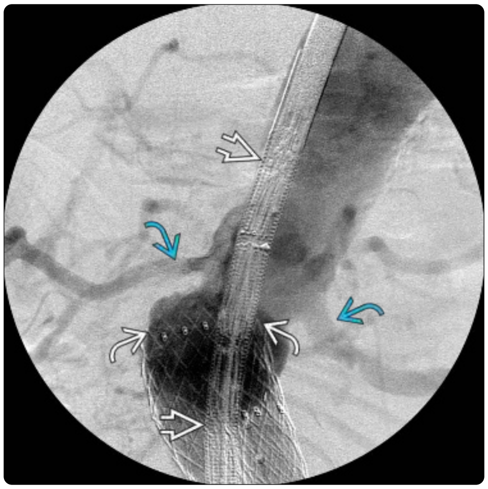


Type IA Endoleak From Migration: Initial Evaluation With 3D CTA

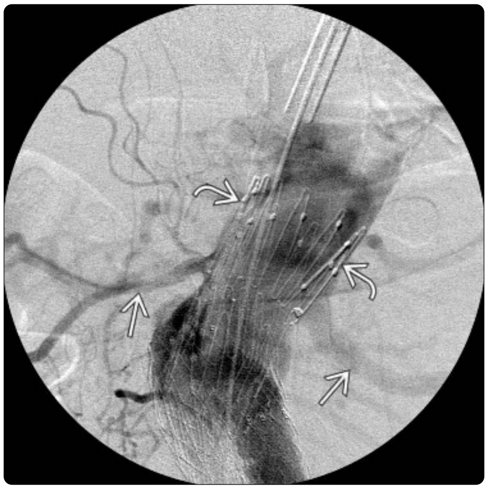


(Left) *Type I endoleaks always require repair. If the AAA sac is enlarging, the rupture risk is significant. DSA during endoleak repair shows the endograft position ↪ below the infrarenal neck. The short distance and angulation between the endograft & the renal arteries ↪ make using an aortic cuff problematic. Conversion to an aorto-uni-iliac endograft was considered a better option. The endograft ⇨ has been introduced.* **(Right)** *DSA after conversion shows suprarenal fixation ↪ securing the device and maintaining renal patency →.*

Type IA Endoleak From Migration: Aorto-Uni-Iliac Endograft Conversion

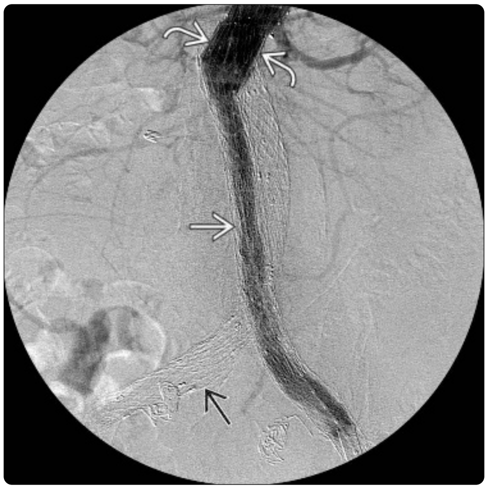


Type IA Endoleak From Migration: Aorto-Uni-Iliac Endograft Conversion

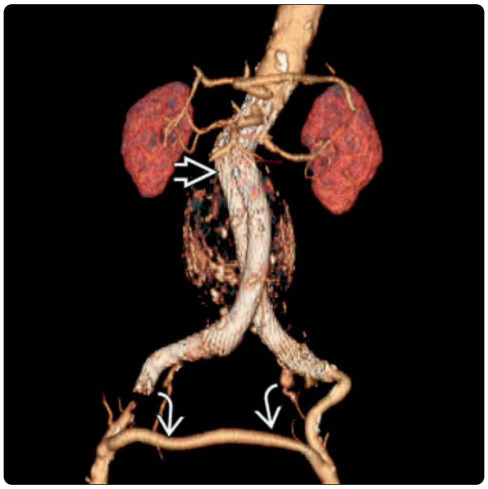


(Left) *DSA after endoleak repair shows no contrast filling the aneurysm sac, an appropriate endograft position ↪, & filling of all critical aortic branches. The aorto-uni-iliac converter extends into the left iliac limb → of the original endograft where it terminates. Thus, the converter excludes the right iliac limb → along with the endoleak.* **(Right)** *Femoro-femoral artery bypass ↪ was surgically placed to maintain right leg perfusion. Postconversion surveillance CTA shows optimal endograft position ⇨ and no endoleak.*

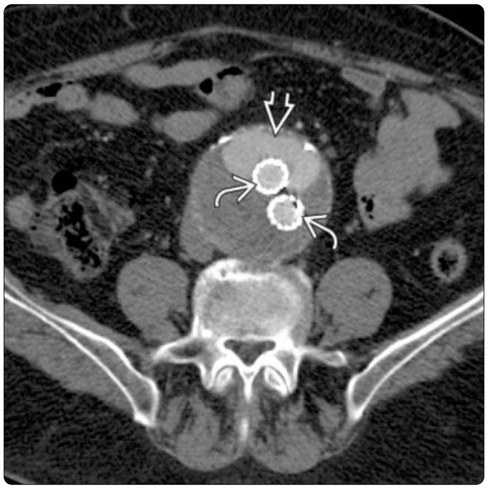
Type IA Endoleak From Migration: Aorto-Uni-Iliac Endograft Conversion



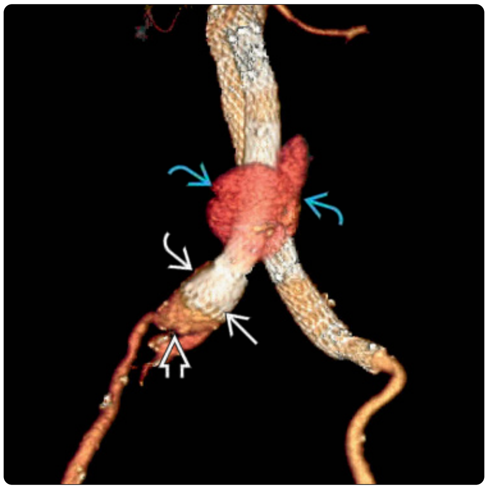
Type IA Endoleak From Migration: Postconversion Surveillance CTA



Type IB Endoleak Repair: Initial Evaluation With CECT

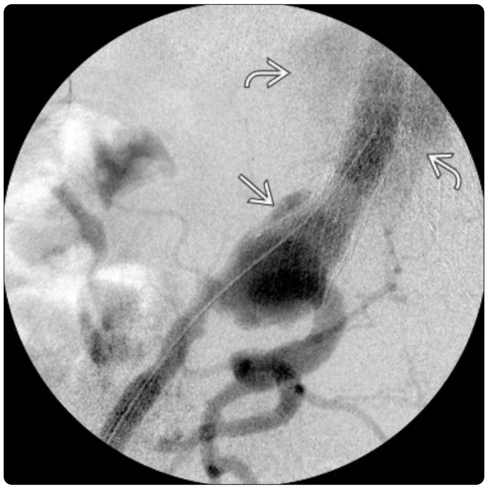


Type IB Endoleak Repair: Initial Evaluation With CTA

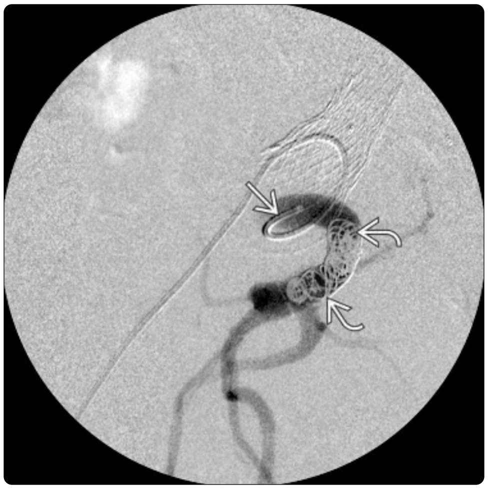


(Left) *CECT 1 month after EVAR shows a large endoleak* ⇨ *anterior to the iliac limbs* ↪ *of the endograft. On more caudal images, the endoleak extended into the distal right common iliac artery alongside the iliac limb. This was felt to represent a type IB endoleak.* **(Right)** *3D reformation shows that the right iliac limb has a flared configuration* ➔ *& ends within a right common iliac artery aneurysm* ⇨*. Distally, the aneurysm extends beyond the endograft, & contrast* ↪ *tracks along the iliac limb. Intrasac contrast* ↪ *from the type IB endoleak is evident.*

Type IB Endoleak Repair: Confirmation of Endoleak Source

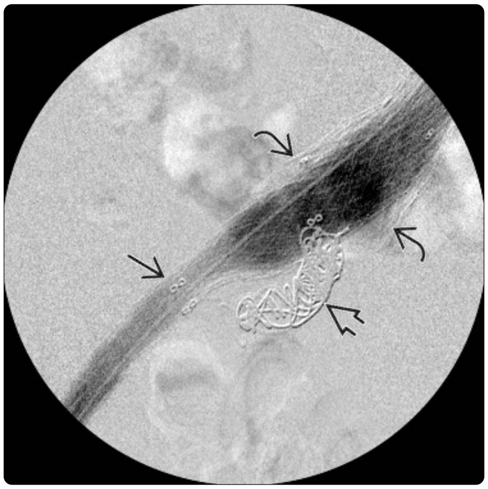


Type IB Endoleak Repair: Hypogastric Coil Embolization

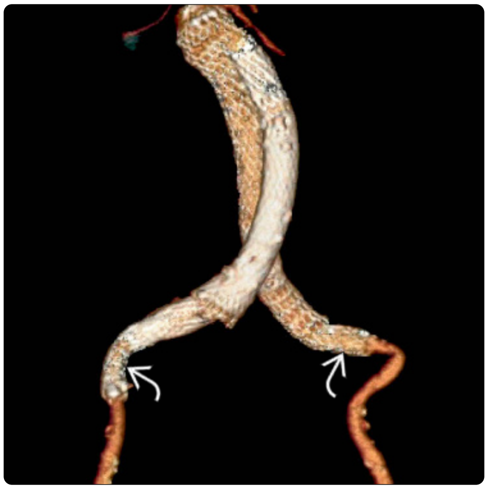


(Left) *DSA via retrograde injection of a femoral access sheath confirms that the endoleak involves the distal attachment of the right iliac limb of the endograft. As a result of an inadequate distal seal, contrast tracks* ➔ *along the iliac limb & is also seen in the AAA sac* ↪*.* **(Right)** *The right internal iliac artery was catheterized* ➔*, & the main trunk was coil embolized* ↪*, both prior to extension of the right iliac limb into the external iliac artery. Embolization was necessary to prevent retrograde common iliac artery perfusion.*

Type IB Endoleak Repair: Distal Extension of Iliac Limb



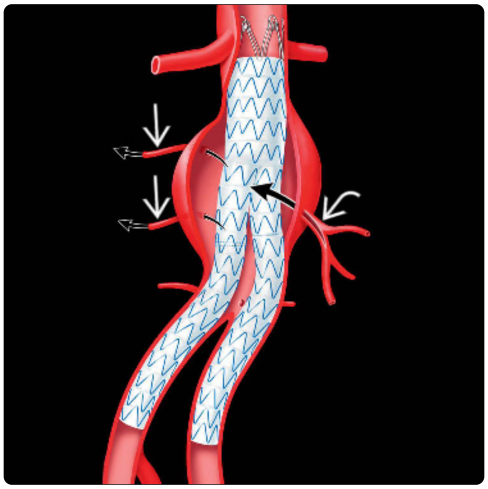
Type IB Endoleak Repair: Postrepair Surveillance



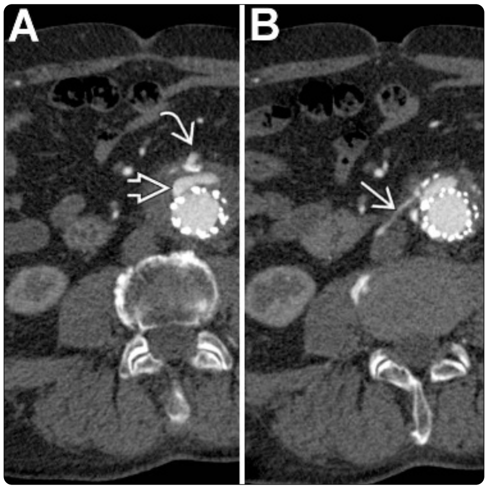
(Left) *An iliac limb extension was placed proximally into the right iliac limb* ↪ *of the original endograft &* ➔ *distally into the external iliac artery. DSA after placement shows that the endoleak is excluded, & the coiled* ⇨ *internal iliac artery does not fill.* **(Right)** *Postrepair 3D CTA shows the endograft after the additional intervention. Due to bilateral common iliac artery aneurysms, both iliac limbs* ↪ *were extended into the external iliac arteries. Although initially avoided on the right, the type IB endoleak necessitated extension.*

(Left) *Graphic shows that, following EVAR, patent side branches arising from AAA can continue to perfuse residual aneurysm sac via an inflow artery ↪, such as the inferior mesenteric artery (IMA), with 1 or more outflow arteries ➡ (e.g., lumbar arteries) allowing egress of blood. The endoleak is analogous to an AVM; the perfused AAA sac acts as a nidus. Endoleak repair requires elimination of this nidus.* **(Right)** *Axial CECT after EVAR shows (A) a type II endoleak ⇨ that is supplied by the IMA ↪. (B) Endoleak outflow is via an accessory renal artery ➡.*

Type II Endoleak Pathophysiology (Aneurysm Perfusion via Side Branches)

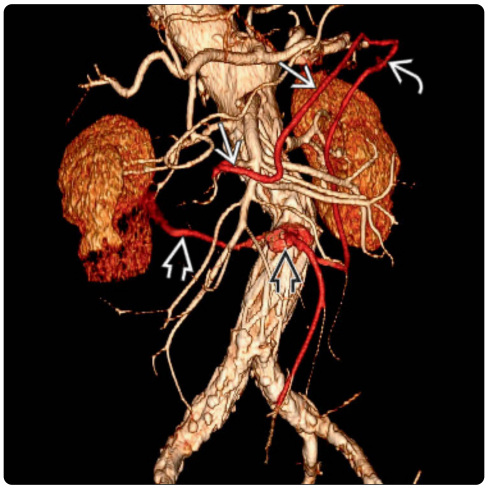


Type II Endoleak Pathophysiology (Endoleak Due to Perfusion via IMA)

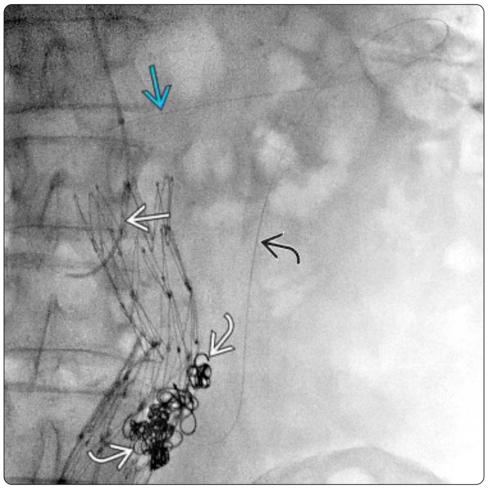


(Left) *CTA reformation shows the pathophysiology of this patient's endoleak. As highlighted in red, the SMA can perfuse the IMA in a retrograde manner. The middle colic artery ➡ anastomoses with the left colic artery ↪ in the splenic flexure. Egress from the endoleak nidus ⇨ is via an accessory lower pole right renal artery ⇨.* **(Right)** *Endoleak repair was done by placing a catheter in the SMA ➡, advancing a microcatheter from the middle colic ➡ to the left colic artery ↪ into the AAA sac, and placing coils ↪.*

Type II Endoleak Pathophysiology (Endoleak Due to Perfusion via IMA)

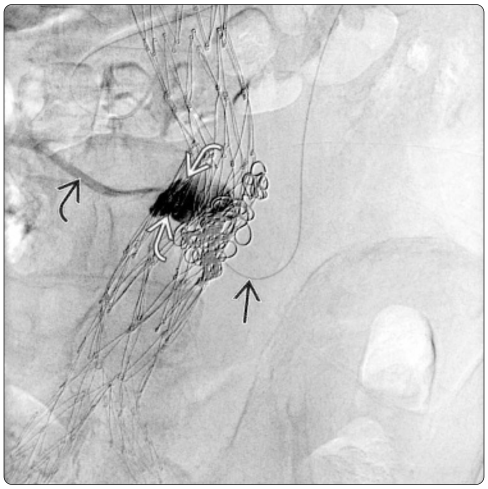


Transarterial Type II Endoleak Repair (Endoleak Nidus Access via SMA)

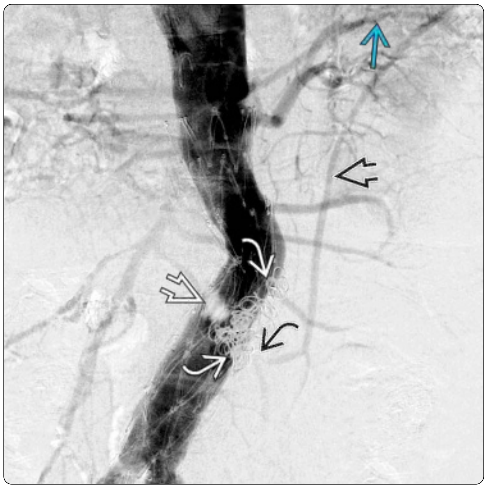


(Left) *Because transcatheter coil embolization did not completely eliminate the endoleak, the liquid embolic agent, Onyx, was introduced into the endoleak nidus via the microcatheter ➡. The Onyx cast fills the nidus ↪ and extends into the accessory lower pole renal artery ↪, thereby occluding outflow.* **(Right)** *DSA after endoleak repair shows coils ↪ & an Onyx cast ⇨ filling the endoleak nidus. The left colic ⇨ & inferior mesenteric ↪ arteries still perfuse via the middle colic artery ➡, but there is no endoleak.*

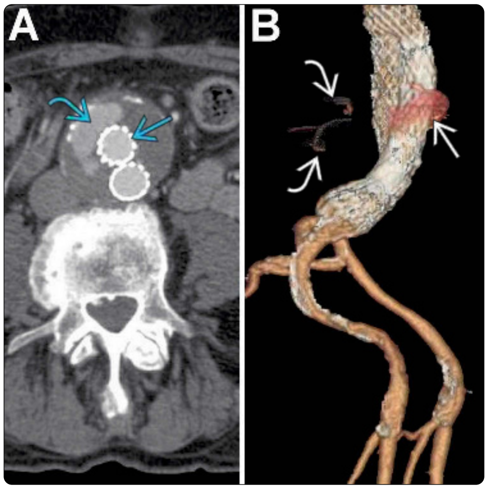
Transarterial Type II Endoleak Repair (Embolization With Coils and Onyx)



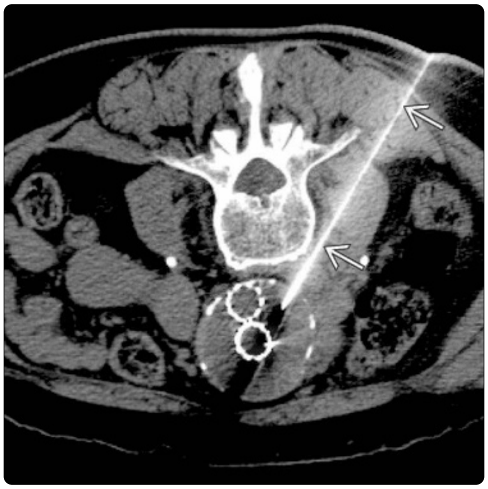
Transarterial Type II Endoleak Repair (Follow-Up DSA After Embolization)



Translumbar Type II Endoleak Repair (Persistent Endoleak on Surveillance)

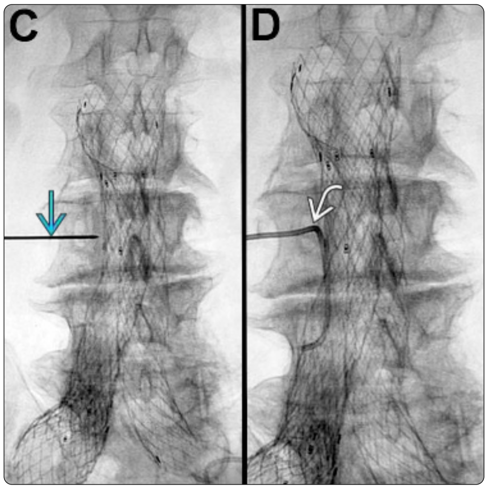


Translumbar Type II Endoleak Repair (Initial AAA Access via CT Guidance)

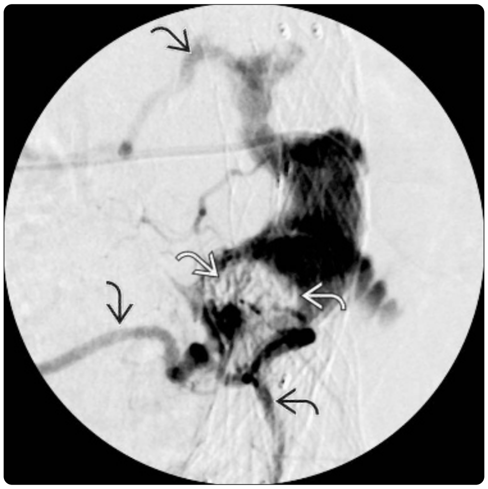


(Left) *(A) Axial CECT shows an endoleak ↪ adjacent to the iliac limb ➡ of an endograft. (B) 3D reformation shows that lumbar arteries ↪ are the source of the endoleak ➡. Serial surveillance CTAs showed endoleak persistence & AAA sac enlargement.* **(Right)** *Axial NECT shows the typical paravertebral needle ➡ course used during translumbar access for type II endoleak repair. Although fluoroscopic guidance & left-sided access are more typical, CT guidance is also used, as in this case in which the endoleak was right-sided.*

Translumbar Type II Endoleak Repair (Needle Exchange for Access Sheath)

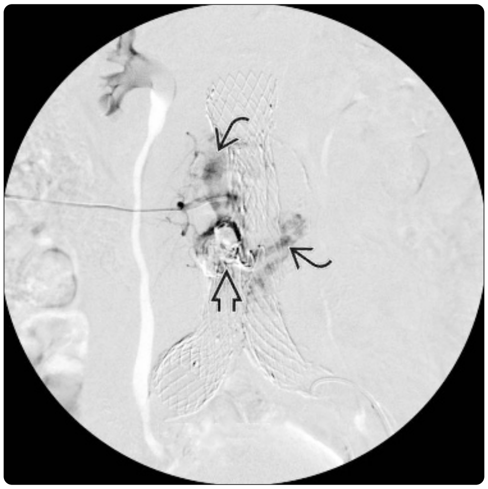


Translumbar Type II Endoleak Repair (Embolization With Coils and Thrombin)

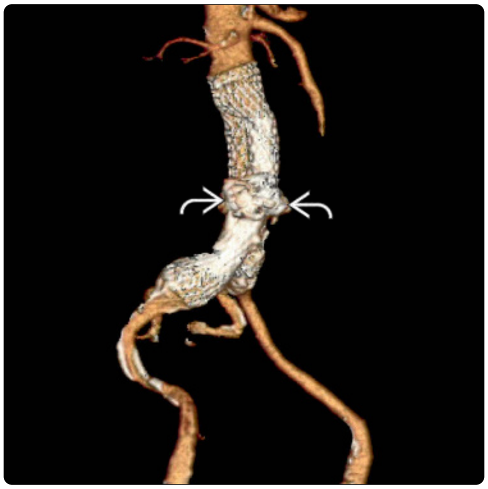


(Left) *(C) After entering the AAA sac with the needle ➡ & removing the stylet, there should be brisk blood return; if not, the needle should be repositioned. (D) A sheath &/or catheter ↪ is then advanced into the sac.* **(Right)** *DSA is performed to determine the extent of the endoleak & to show the feeding vessels. This endoleak has multiple lumbar feeders ↪. The endoleak nidus & feeders are embolized with liquid &/or mechanical embolic agents. Thrombin & coils have been placed in the inferior part ➡ of the endoleak nidus.*

Translumbar Type II Endoleak Repair (Follow-Up Postembolization DSA)



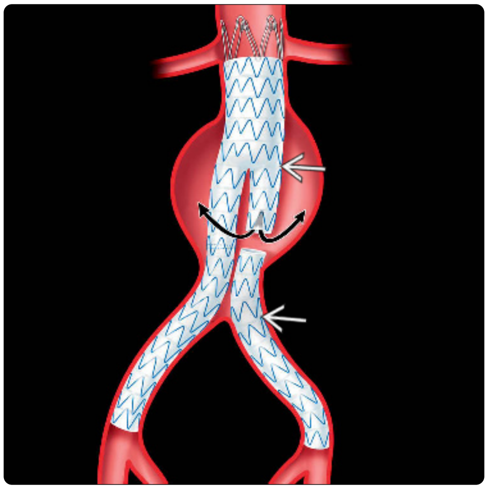
Translumbar Type II Endoleak Repair (Follow-Up CTA After Embolization)



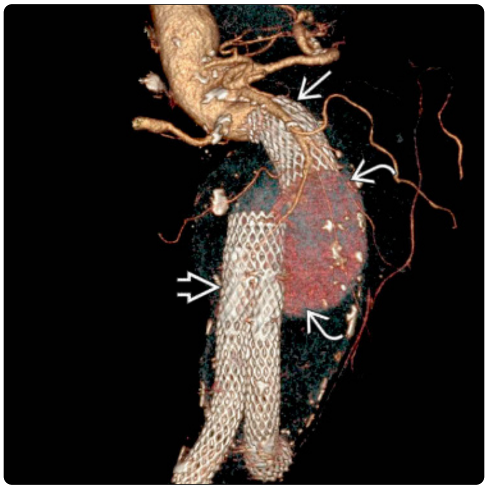
(Left) *DSA after embolization shows coils ⇨ inferiorly in the endoleak nidus. Only small amounts of contrast ↪ enter the endoleak cavity, & there is no opacification of any arterial feeders. Although this is consistent with a successful endoleak repair, it is essential that surveillance imaging be continued afterward as recurrence is possible.* **(Right)** *3D reformation after endoleak repair shows that the embolics ➡ have the same distribution as that of the endoleak seen on the preintervention CTA, & lumbar feeding arteries are no longer present.*

(Left) *Type III endoleaks are due to a mechanical problem with the endograft. Possible mechanical issues include tears in the endograft fabric, metallic stent fractures, & poor sealing or separation of overlapping modular graft components →, as shown in this graphic. In all instances, the AAA sac is reperfused (curved black arrows).* **(Right)** *3D reformation in a patient with hypotension & abdominal pain 1 year after EVAR shows separation of an aortic cuff → from a bifurcated endograft body ⇨ and a large type III endoleak ↪.*

Type III Endoleak Repair: Compromised Endograft Integrity

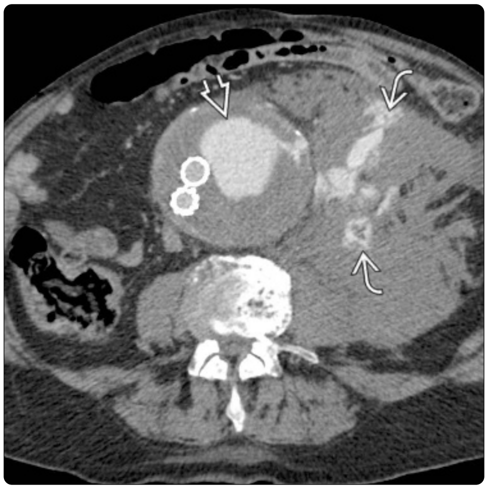


Type III Endoleak Repair: Endograft Component Separation

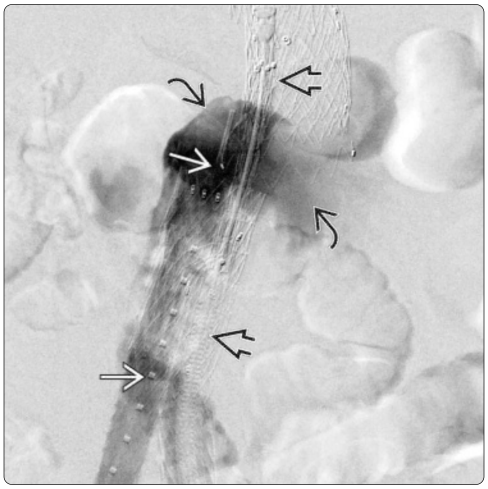


(Left) *Axial CECT shows that the endoleak ⇨ has caused AAA rupture with contrast extravasation ↪ evident in the periaortic hematoma. All type III endoleaks must be repaired when identified as exposure of the AAA to systemic blood has a high rupture risk.* **(Right)** *Type III endoleak repair often requires placement of new endograft components. DSA via a flush catheter → placed through the right iliac limb shows the endoleak ↪. A new endograft ⇨ has been introduced from the left, bridging the separated components.*

Type III Endoleak Repair: Aneurysm Rupture From Endoleak

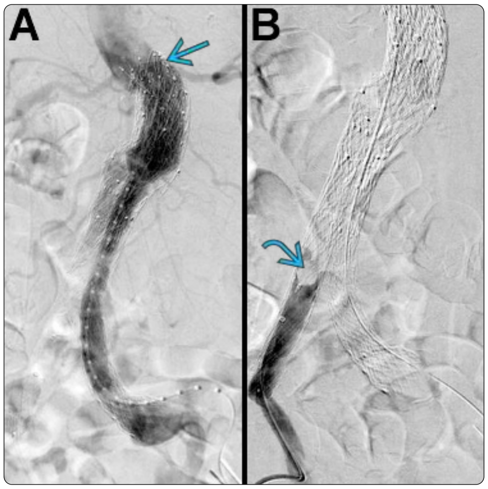


Type III Endoleak Repair: Endoleak Evaluation With DSA

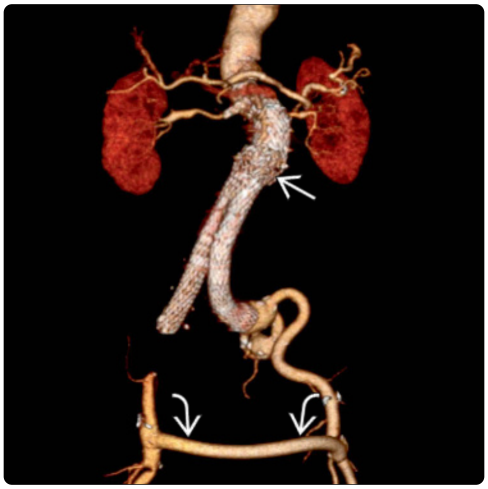


(Left) *(A) An aorto-uni-iliac converter endograft → with suprarenal fixation was used for the endoleak repair. After placement, the endoleak is no longer seen. (B) The right iliac limb was sealed with a plug occluder ↪ to prevent retrograde reperfusion.* **(Right)** *Coronal CTA after endoleak repair shows that the patient also underwent a femoro-femoral artery bypass ↪, which is required in all cases involving an aorto-uni-iliac endograft. There is now an intact endograft → that excludes the AAA while perfusing critical arteries.*

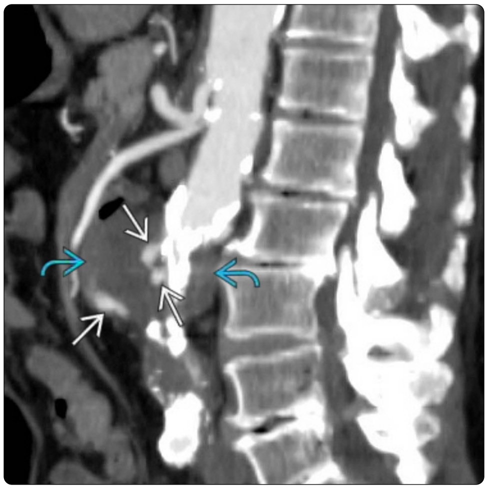
Type III Endoleak Repair: Aorto-Uni-Iliac Conversion



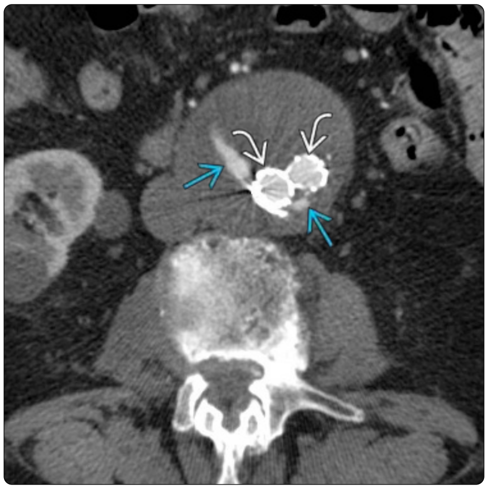
Type III Endoleak Repair: Surveillance CTA After Repair



Repair of Endoleak of Undetermined Type (Initial CTA Evaluation of Endoleak)

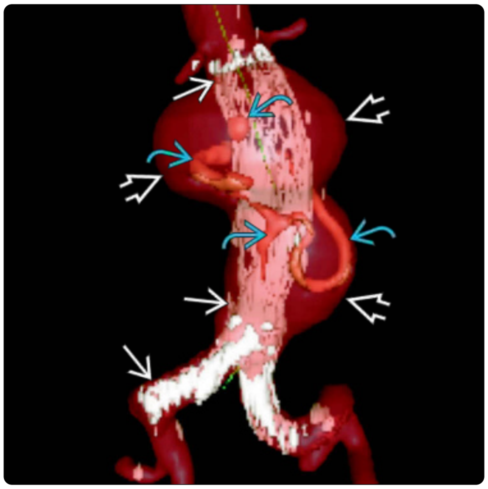


Repair of Endoleak of Undetermined Type (Initial CTA Evaluation of Endoleak)

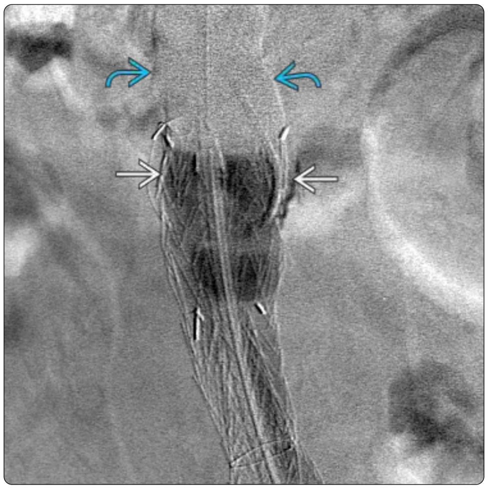


(Left) *One year after a patient underwent EVAR for a large bilobed AAA, surveillance CECT imaging demonstrated continued growth of the residual AAA sac ↪ along with multiple foci of contrast accumulation → within the sac.* **(Right)** *On axial images, contrast → could be seen adjacent to both the endograft body and limbs ↪. Despite obtaining CT images in multiple planes and delayed sequences, along with ultrasound evaluation, it was unclear as to which type of endoleak was responsible for the continued sac growth.*

Repair of Endoleak of Undetermined Type (Initial CTA Evaluation of Endoleak)

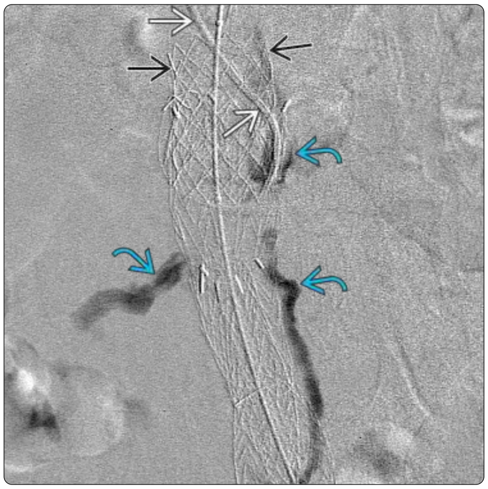


Repair of Endoleak of Undetermined Type (Placement of Aortic Extension Cuff)

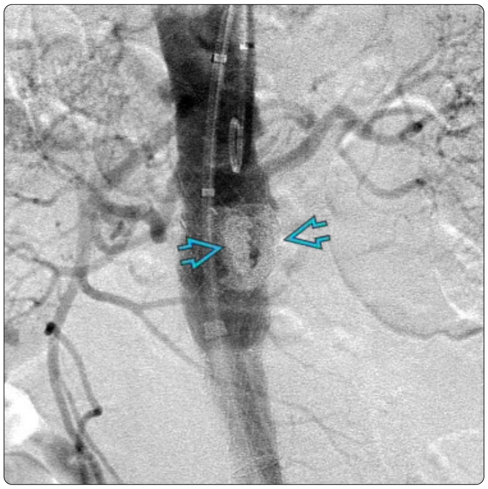


(Left) *Prior to proceeding with repair of the endoleak, a postprocessed 3D image from the delayed-phase CECT was reviewed so as to better plan the appropriate intervention. This clearly showed the relationship between the endograft → and the AAA sac ⇨ and also showed multiple endoleak contrast channels ↪ within the sac that suggested type I endoleak.* **(Right)** *An aortic extension cuff → was deployed at the proximal attachment site and was distended with a large-caliber compliant balloon ↪ so as to maximize the seal zone.*

Repair of Endoleak of Undetermined Type (DSA Demonstrating Persistent Endoleak)



Repair of Endoleak of Undetermined Type (Successful Treatment With Onyx)



(Left) *After deploying and distending the aortic extension cuff →, contrast was injected via a catheter → that had been introduced from a left brachial artery access and had been placed between the cuff and aneurysm neck in the proximal seal zone. DSA demonstrated persistent endoleak channels ↪ as had been seen on the 3D imaging.* **(Right)** *Onyx ⇨ was used to embolize the persistent endoleak channel that had been identified by DSA within the proximal seal zone, thereby eliminating type I endoleak.*

Pulmonary Arteries: Revascularization (PE Thrombolysis)

KEY FACTS

TERMINOLOGY

- Pulmonary embolism (PE) classified as massive, submassive, or low risk

PREPROCEDURE

- CT pulmonary angiography gold standard for diagnosis of PE in patients without contraindications to receiving iodinated contrast material
- Wells criteria and D-dimer should be used to risk stratify stable patients with suspected PE

PROCEDURE

- Mainstay of treatment for low-risk and subset of submassive PEs is anticoagulation
- Catheter-directed therapies: Can be performed rapidly in hemodynamically unstable patients with multiple comorbidities and massive or submassive PE
    - Mechanical thrombus disruption
    - Catheter-directed thrombolysis
    - Combination of mechanical disruption and direct thrombolytic infusion thought to be most efficacious

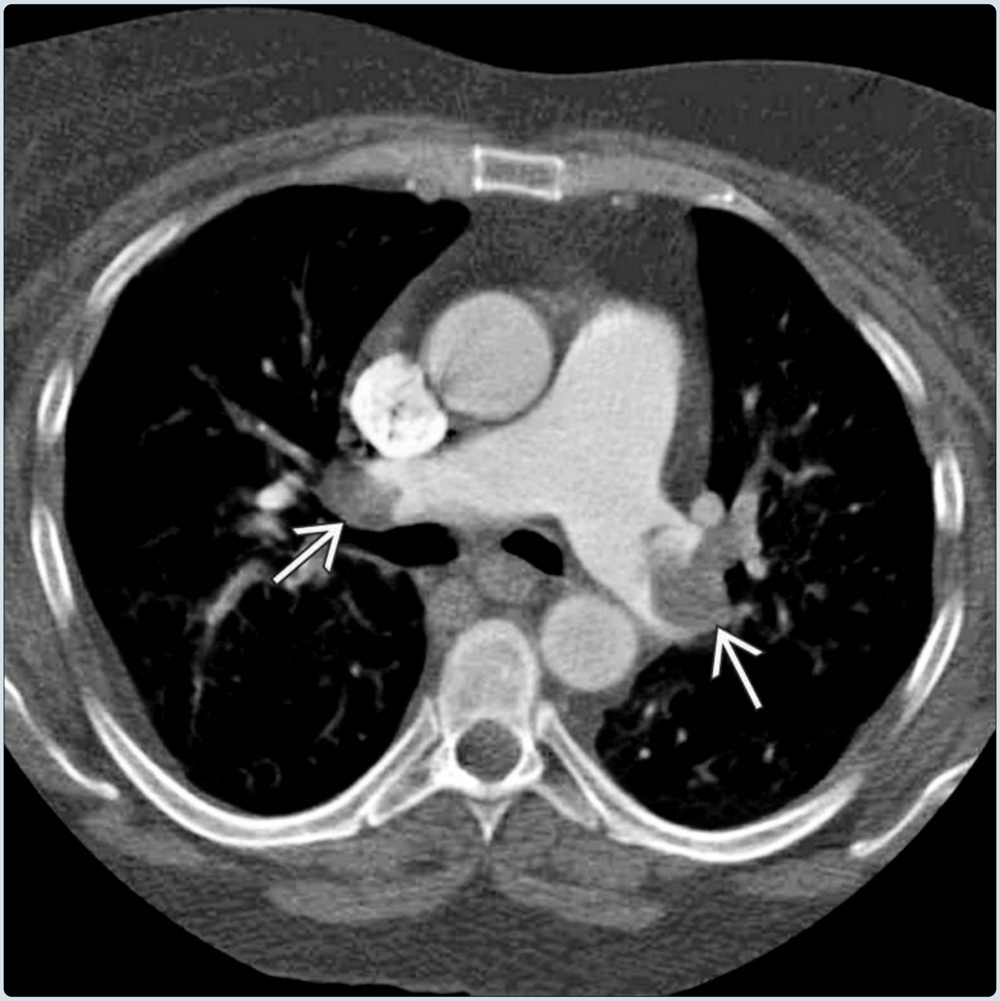
POST PROCEDURE

- Patient should be in ICU post procedure
- Access site monitoring, neuro checks, bleeding assessment, fibrinogen, PT/PTT every 4-8 hours

OUTCOMES

- Catheter-directed modalities have demonstrated high efficacy with favorable side effect profile when compared to systemic thrombolysis and surgical thrombectomy
- Clinical success rates of catheter-directed therapies defined by hemodynamic improvement, resolution of hypoxia, and survival to discharge have been reported to be as high as 85.7% in massive PE and 97.3% in submassive PE
- Procedure-related complication rate: 7.9%
    - Major complication rate: 2.4%

Bilateral Emboli



Axial CECT shows large, bilateral emboli in the main pulmonary arteries (PAs) ➡. Additionally, CT should be examined for signs of PA hypertension (enlarged PA trunk), right ventricular strain (right ventricular dilatation, flattening of the interventricular septum, or contrast reflux into IVC/hepatic veins), and pulmonary infarction.

TERMINOLOGY

Abbreviations

- Pulmonary embolism (PE)

Definitions

- **Massive PE**
  - Acute PE with sustained hypotension (systolic BP < 90 mm Hg or decrease from baseline of 40 mm Hg for > 15 min or pulseless or persistent bradycardia < 40 bpm)
  - Mortality > 50% at 90 days
  - 5% of patients present with massive PEs
- **Submassive PE**
  - Acute PE without hypotension
  - Mortality estimated: 16-22% at 90 days
  - Signs of right ventricular (RV) dysfunction or myocardial necrosis
  - 40% of patients present with submassive PE
- **Low-risk PE**
  - Acute PE and absence of clinical markers that define massive or submassive
  - Mortality estimated 15% at 90 days
  - 55% of patients present with low-risk PE

Overview

- Incidence of PE in United States ~ 900,000 per year
- Deep vein thrombosis (DVT) most common cause of PE
- PE and DVT results in up to 100,000 deaths per year in United States

Symptoms of PE

- Chest pain
- Dyspnea
- Diaphoresis
- Palpitations
- Syncope
- Cough
- Hemoptysis
- Lower extremity swelling

Diagnostic Approach

- Wells score should be calculated to risk stratify patients with suspected PE if patient stable
- D-dimer: Fibrin degradation product
  - Used in moderate or low pretest probability of PE to further stratify patients
  - D-dimer > 500 μg/L warrants further work-up
  - D-dimer may be falsely elevated in other conditions (pregnancy, rheumatologic conditions, malignancy, and liver disease)
- CT pulmonary angiography (CTPA) definitive imaging modality for diagnosis of PE
- Ventilation/perfusion scan can be obtained if patient cannot receive intravenous contrast due to allergy or preexisting condition

Treatment of Low-Risk PE and Submassive PE

- Mainstay of treatment is anticoagulation
- Anticoagulants can be administered parenterally, orally, or subcutaneously
- Most commonly used parenteral anticoagulant is unfractionated heparin; however, it is only used in short-term as "bridge" to oral or subcutaneous long-term option
- Long-term options include warfarin (vitamin K antagonist), novel oral anticoagulants (NOACs) such as rivaroxaban, apixaban, dabigatran, or low molecular weight heparin
- Oral anticoagulant options include warfarin and NOACs
  - Warfarin therapy most cost effective but requires regular interval monitoring of patient’s international normalized ratio (INR)
  - NOACs do not require therapeutic monitoring
- Patient's renal function, comorbidities, and preference should be taken into account when selecting anticoagulation regimen
- In cases of massive and some submassive PEs, systemic doses of thrombolytic drugs such as tissue plasminogen activator (systemic thrombolysis) or invasive therapies required for treatment

Catheter-Directed Therapies

- Can be performed rapidly in hemodynamically unstable patients with multiple comorbidities
- Multiple endovascular therapies have been developed to break up up clot directly at point of occlusion
  - Mechanical thrombus disruption
    - Suction
    - Fragmentation
  - Catheter-directed thrombolysis
    - Pharmacologic techniques result in lower doses of thrombolytics when compared to systemic thrombolysis
    - Lower risk of bleeding events since thrombolytic directly delivered into pulmonary arteries (PAs)
    - Currently, literature is mixed whether US-assisted catheter directed thrombolysis is more efficacious than standard catheter-directed thrombolysis
      - US-assisted catheter-directed thrombolysis (pharmacomechanical technique) in both massive and submassive PE has shown significant reduction in RV/left ventricular diameter ratio, mean PA peak systolic pressure, and PA angiographic obstruction over 48 hours
- Combination of mechanical disruption to expose more surface area of thrombus and direct thrombolytic infusion is currently thought to be most efficacious technique

Signs of RV Dysfunction

- Imaging
  - Right ventricle displaced toward left ventricle (ratio > 0.9 on CT or echo)
  - RV dilatation
  - Contrast reflux into IVC or hepatic veins
- EKG: RV strain; ischemic strain
- Laboratory: Elevated troponin or proBNP

PREPROCEDURE

Indications

- Patients with massive or submassive PE
  - Must have reserve to tolerate endovascular procedure
  - Failed systemic thrombolysis
  - Multiple comorbidities and poor surgical candidates

  - Patients benefit from catheter-directed therapies that aim to reduce clot burden rapidly and restore hemodynamic stability
  - Patients with submassive PE benefit from catheter directed therapies by preventing clot progression to massive PE, which can result in RV failure and pulmonary hypertension

Contraindications

- Patients with contraindications to pharmacologic thrombolysis may undergo mechanical thrombectomy
- Absolute contraindications
  - Active internal bleeding
  - Absolute contraindication to anticoagulation
  - Contraindications to thrombolytic drugs
  - Recent neurosurgery
  - Stroke or intracranial trauma within 3 months
- Relative contraindications
  - Stroke within 6 months
  - Intracranial neoplasm
  - Arteriovenous malformation
  - Aneurysm
  - Recent gastrointestinal bleed within 3 months
  - Bleeding diathesis or thrombocytopenia
  - Uncontrolled hypertension
  - Pregnancy
  - Severe renal &/or hepatic dysfunction

Getting Started

- Things to check
  - Informed consent for conscious sedation and analgesia, procedure, risks of sedation and procedure, benefits of procedures, alternatives and risks of not having procedure done
  - Coagulation studies and baseline labs (platelet count, PT/INR, aPTT, CBC, U/A, BMP)
  - EKG to evaluate for left bundle branch block (LBBB)
    - Catheter-directed thrombolysis can lead to right bundle branch block (RBBB); thus, if patient has preexisting LBBB, procedure could lead to complete heart block
  - Placement of temporary pacer if patient has LBBB
  - Review of cross-sectional imaging such as chest CTA
  - Marking of access site(s)
- Equipment list
  - US and micropuncture access kit
  - Basic angiography kit
  - 7-Fr vascular sheath
  - Berman wedge catheter
  - Exchange length Rosen wire and Bentson wire
  - Pressure transducer kit
  - Isoosmolar contrast
  - US-assisted thrombolytic infusion system

PROCEDURE

Procedure Steps

- Sterile prep of internal jugular location (preferred sites: Right internal jugular > left internal jugular > femoral)
- Venous access using needle via Seldinger technique followed by exchange with micropuncture set to pass guidewire then exchange for vascular sheath
- Insertion of Berman Wedge and then inflation of balloon with air in right atrium (RA)
- Connection of catheter up to pressure transducer and to obtain RA and RV pressures
- Balloon catheter then advanced through tricuspid valve into RV and into PA
- Obtain PA pressures and simultaneous systemic blood pressure (cycle blood pressure cuff)
  - Normal RA pressure: 2-6 mm Hg
  - Normal RV pressure (systolic): 15-25 mm Hg
  - Normal RV pressure (diastolic): 8-15 mm Hg
  - Normal PA pressure: 8-20 mm Hg
  - Pulmonary hypertension: > 25 mm Hg
- ± PA angiogram in main PA, then if PA pressures are elevated, injection rates should be lowered
  - PA-gram typically not performed, as we obtain CTPA prior to recommending catheter-directed thrombolysis
- Advance inflated balloon wedge catheter into target PA
- Advance exchange length Rosen wire (support) into lower lobe PA
- Deflate balloon and remove Berman wedge, place infusion system, set up per manufacturer specifications, and flush frequently so sideholes do not become occluded
- Suture sheaths to patient and tie catheters to sheath
- Infuse tPA (standard is to deliver total of 24 mg); typically infuse at 1 mg per hour per catheter
- Infuse heparinized saline through sheath(s)
- ± low goal heparin protocol through IV during thrombolytic infusion

Alternative Procedures/Therapies

- Surgical
  - Surgical thrombectomy
    - Surgical, open approach to remove clot from PAs
    - Also indicated in very unstable patients that require immediate therapy &/or extracorporeal membrane oxygenation
    - Surgical thrombectomy carries high mortality (estimated 6-46%, depending on patient's characteristics)
- Other
  - Systemic thrombolysis
    - Involves injection of tPA, streptokinase, or urokinase through peripheral IV delivering systemic dose of thrombolytic with goal of clot lysis
      - Systemic thrombolysis should be started for hemodynamically unstable massive PEs and certain submassive PEs
      - Systemic thrombolysis has higher risk of bleeding complications when compared to catheter-directed therapies (estimated rate of 22% for significant hemorrhage and rate of 3-5% for intracranial bleeds)

POST PROCEDURE

Things To Do

- Patient should be in ICU post procedure
- Access site monitoring, neuro checks, bleeding assessment every 4 hours
- Fibrinogen, PT/PTT every 8 hours

Wells Score for PE

Criteria	Points
Clinical signs and symptoms of DVT	3
PE number 1 diagnosis	3
Heart rate > 100	1.5
Immobilization > 3 days or surgery in previous 4 weeks	1.5
Prior history of DVT or PE	1.5
Hemoptysis	1
Malignancy	1

DVT = deep vein thrombosis; PE = pulmonary embolism.

Catheter-Directed Therapies

Type	Mechanism
Standard catheter-directed thrombolysis	Pharmacologic: Infusion of thrombolytic directly into thrombus
Ultrasound-assisted thrombolysis	Pharmacomechanical: High-frequency ultrasound disrupts thrombus structure, exposing greater surface area to thrombolytic infusion
Thrombus fragmentation	Mechanical: Fragmentation of thrombus by rotating catheter to break up clot
Suction embolectomy	Mechanical: Aspiration of thrombus

  - If fibrinogen < 150 but > 100, tPA dose should be cut in half; if fibrinogen < 100, tPA should be stopped and replaced with full dose heparin, and cryoprecipitate should be administered to replete fibrinogen
- After full dose of tPA delivered, catheters can be used to determine PA pressures to assess immediate effect of therapy
- Remove sheaths and start standard goal heparin protocol per institution

OUTCOMES

Complications

- Most feared complication(s)
  - Major procedure-related complication rate: 2.4%
    - Groin hematomas requiring transfusion
    - Noncerebral hemorrhage requiring transfusion
    - Massive hemoptysis requiring transfusion
    - Renal failure requiring hemodialysis
    - Cardiac tamponade requiring surgical intervention
    - Bradyarrhythmia
    - Widespread distal embolization
    - Cerebrovascular hemorrhage
    - PA perforation
    - Death
- Other complications
  - Minor procedure-related complication rate: 7.9%
    - Groin hematoma, bradycardia, minor hemoptysis

Expected Outcomes

- Clinical success rates of catheter-directed therapies defined by hemodynamic improvement, resolution of hypoxia, and survival to discharge have been reported to be as high as 85.7% in massive PE and 97.3% in submassive PE
- Multidisciplinary rapid response teams, including interventionalists, have been developed at several major medical centers to rapidly triage and treat hemodynamically significant PEs

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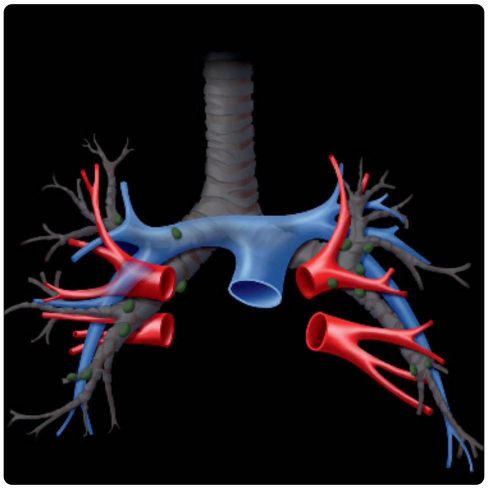
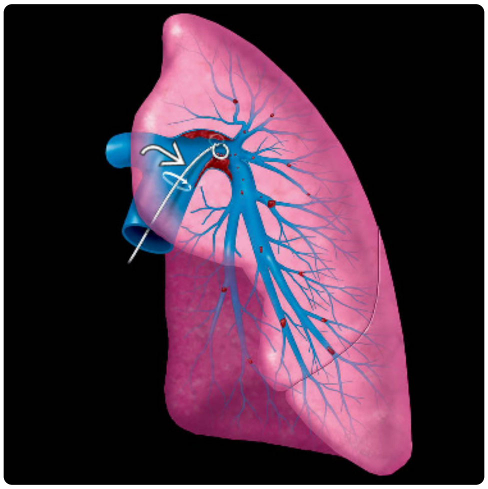
(Left) *Graphic depicts the anatomy and relationships of the PAs (blue) and veins (red) and the tracheobronchial tree.* **(Right)** *Catheter-mediated fragmentation of thrombus involves advancing a pigtail catheter* ➡ *into a proximal embolus and then rotating it to macerate the clot. Systemic anticoagulation must be delivered prior to this maneuver. Although thrombus fragments will embolize distally, overall PA blood flow should improve, thereby decreasing PA pressure.*

Pulmonary Vascular Anatomy

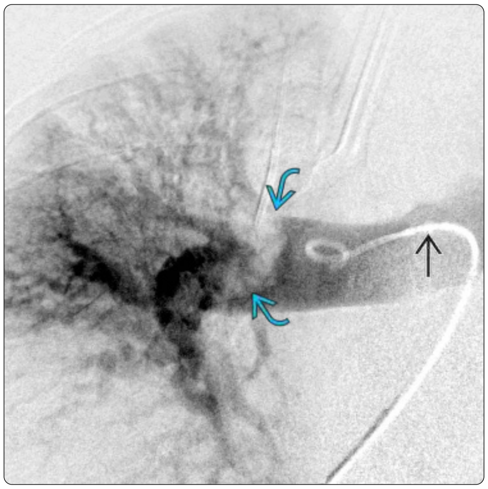


Massive Left Main Pulmonary Emboli (Catheter-Mediated Fragmentation)

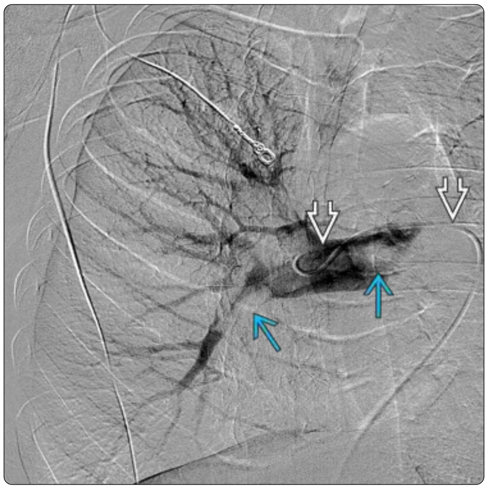


(Left) *DSA via a pigtail catheter* ⇨ *in the right PA shows a large filling defect* ↪ *consistent with pulmonary embolus. Pressure measurements can be obtained via this catheter to help aid treatment decisions.* **(Right)** *In this case (different patient), after confirming adequate systemic anticoagulation, 6 mg tPA (diluted in 30 mL normal saline) was vigorously pulsed through the catheter as it* ➡ *was spun to fragment clot* ⇨*. IV heparin was then continued in the ICU.*

Right Pulmonary Emboli: Diagnostic

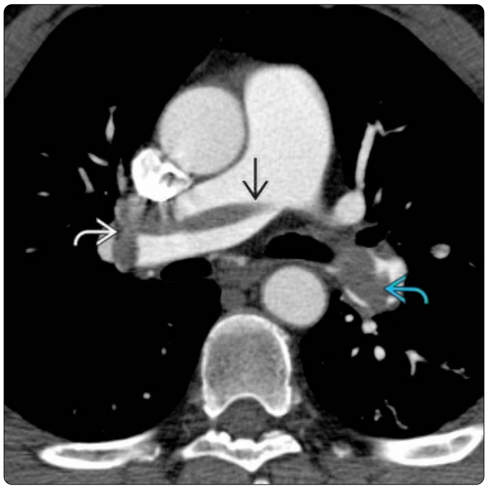


Right Pulmonary Emboli: Therapeutic

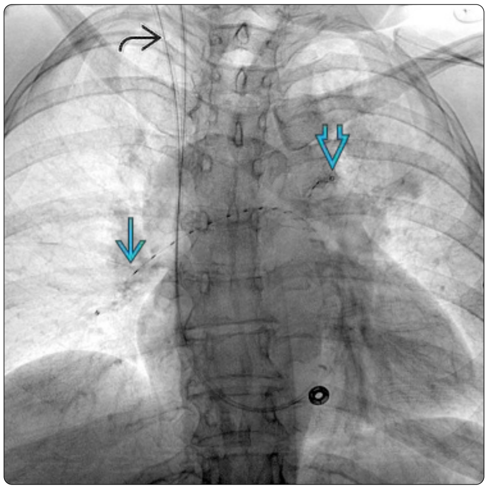


(Left) *Axial PA CECT shows a saddle embolus* ⇨ *extending from the main PA into both the right* ➡ *and left* ↪ *PAs.* **(Right)** *The saddle pulmonary embolism was treated with bilateral catheter-directed thrombolysis. A US-assisted thrombolytic catheter* ⇨ *is present in the right PA; a traditional infusion catheter* ⇨ *is present in the left PA. Two internal jugular sheaths* ↪ *were placed to allow passage of the 2 infusion catheters.*

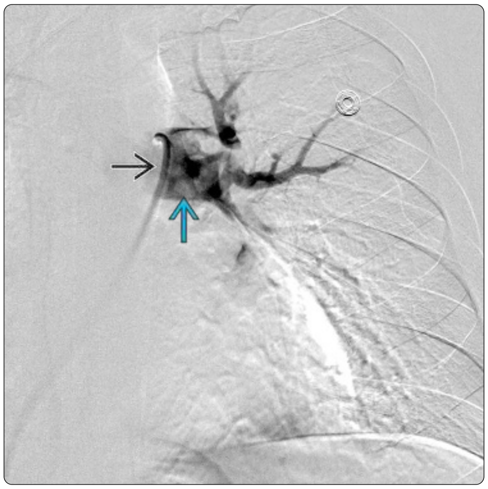
Massive Saddle Pulmonary Emboli (Pulmonary CT Angiography)



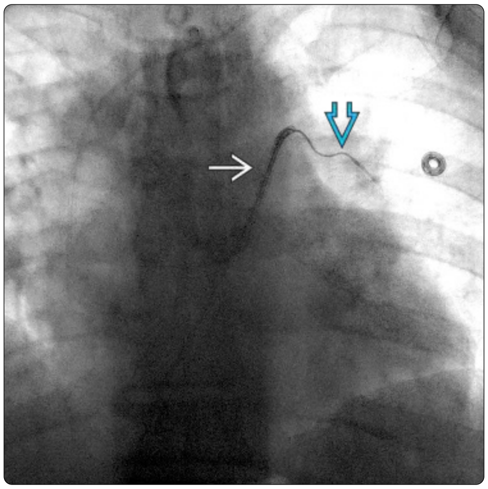
Massive Saddle Pulmonary Emboli (Catheter-Directed Thrombolysis)



Massive Pulmonary Emboli: Left Pulmonary Arteriogram

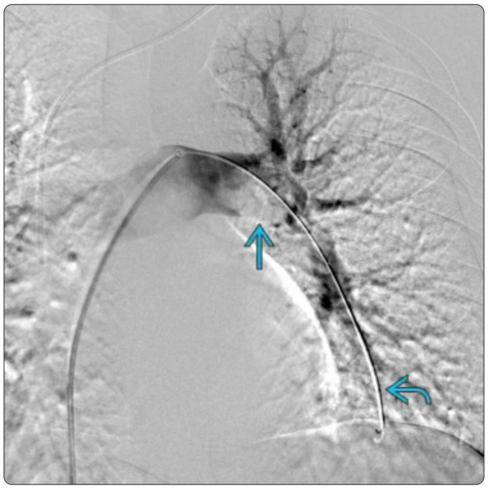


Massive Pulmonary Emboli: Mechanical Fragmentation

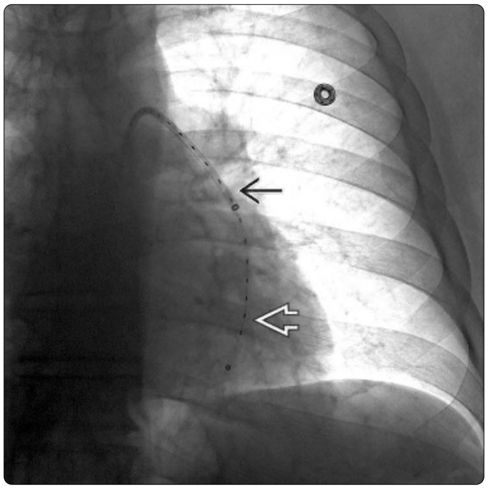


(Left) *A 58-year-old man with colorectal malignancy presented with a massive saddle pulmonary embolism. After performing a pulmonary arteriogram, an 8-Fr sheath ⇨ was advanced into the left PA. DSA confirms significant thrombus burden ⇨ within the left main PA.* **(Right)** *After administration of IV heparin, mechanical fragmentation of the left PA thrombus was performed with a sine-shaped wire ⇨ (pigtail catheter may be used) via the sheath ➡.*

Massive Pulmonary Emboli: Post Fragmentation

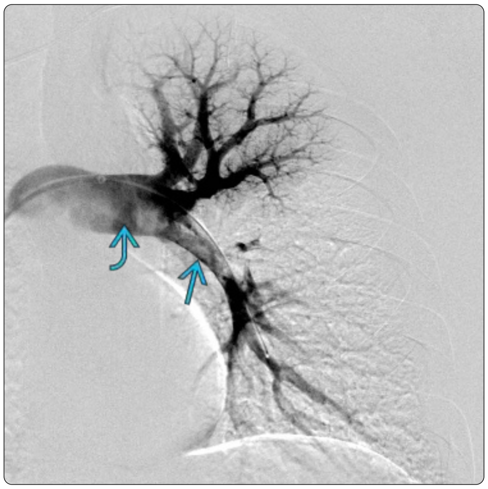


Massive Pulmonary Emboli: Catheter-Directed Thrombolysis

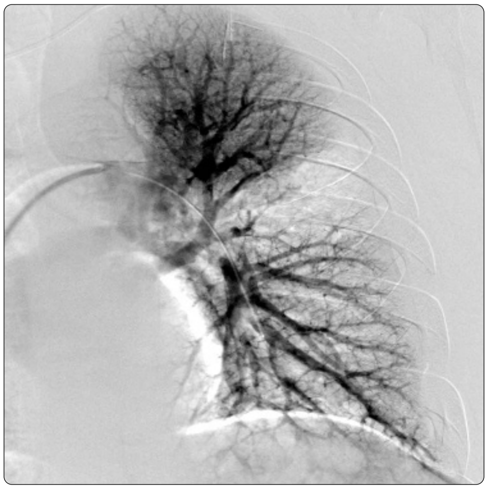


(Left) *Subsequent pulmonary angiogram shows improved flow within the left lung PAs; however, residual thrombus ⇨ remains. A 0.035" wire ⇨ has been advanced through the sheath into the left lower lobe PA.* **(Right)** *An infusion catheter ➡ (US-assisted in this case) was advanced over the wire, and tPA infusion was performed at 1 mg/hour. The sheath ⇨ was subsequently withdrawn slightly.*

Massive PE: Post Catheter-Directed Thrombolysis Angiogram (Arterial Phase)



Massive PE: Post Catheter-Directed Thrombolysis Angiogram (Venous Phase)



(Left) *Pulmonary angiogram was obtained after 20 hours of catheter-directed thrombolysis. A large thrombus remains in the left lower lobe PA ⇨, but the left main PA ⇨ is now free of thrombus.* **(Right)** *Parenchymal and venous phase of the same pulmonary angiogram reveals occlusion of flow within the superior segment of the left lower lobe. The determination of whether to continue catheter-directed thrombolysis should be dependent on the clinical picture and PA pressure measurements.*

Pulmonary Arteries: Exclusion (Pulmonary AVM)

KEY FACTS

TERMINOLOGY

- **Pulmonary arteriovenous malformation (PAVM)**
    - High-flow, low-resistance fistulous communication between pulmonary artery and vein
    - PAVMs potential source for paradoxical emboli; can cause stroke, brain abscess
    - Should treat if feeding artery ≥ 3 mm in diameter

PROCEDURE

- Superselectively catheterize artery feeding target
- Coiling and plugging procedures
- Place tip of coil in small side branch proximal to target; allow to prolapse into feeding vessel
- Embolize within 1 cm of nidus
- Oversize 20-50% for all plugs except for Micro Vascular Plugs, which are matched
- Ensure that coils are tight and dense to prevent recanalization

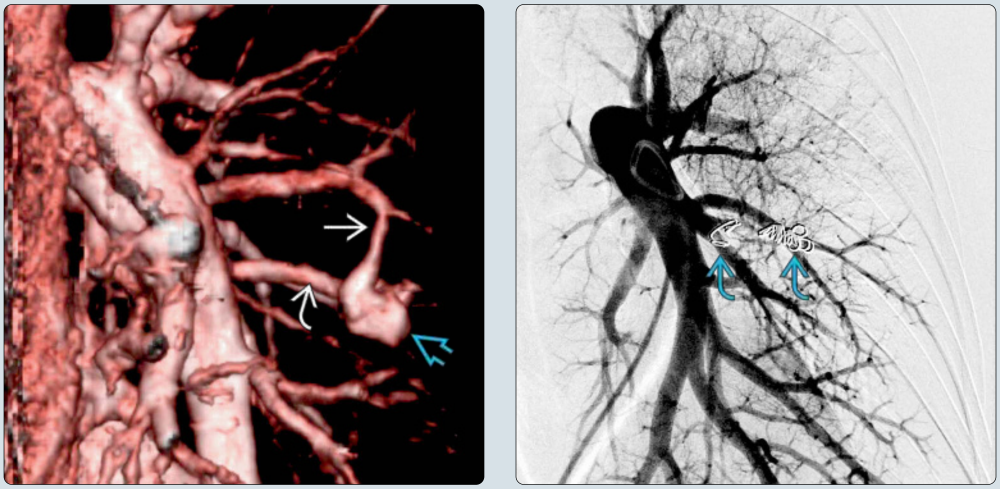
POST PROCEDURE

- Chest CT at 1-3 months to reestablish baseline
- Follow-up after AVM embolization every 3-5 years

OUTCOMES

- **PAVM embolization complications**
    - Paradoxical embolization of embolic agent (rare) into systemic arterial circulation
    - Intraprocedural iatrogenic air embolization (< 5%)
        - May enter brain, leading to stroke
        - May enter left coronary artery (anteriorly located), causing chest pain and bradycardia
    - Self-limited postembolization pleurisy: 14-31%
- **Expected outcomes**
    - > 95% initial success rate in PAVM treatment following transcatheter embolization
    - Recanalization of embolized segments reported in up to 25% of embolizations, usually when coils are deployed

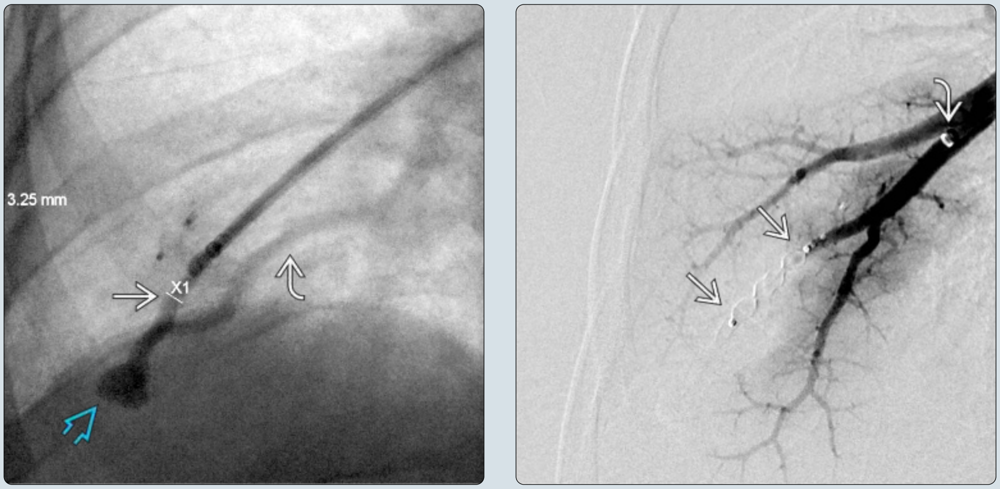
(Left) *Dyna CT 3D reformation from a pulmonary DSA in a patient with hereditary hemorrhagic telangiectasia (HHT) shows a simple pulmonary arteriovenous malformation (PAVM)* ⇨ *with a single feeding artery* ➡ *and a single draining vein* ⤴. **(Right)** *Left pulmonary artery DSA shows multiple embolization coils* ⇨ *that were placed in the subsegmental pulmonary artery supplying the AVM. Occlusion of the AVM prevents possible paradoxical embolization.*



Simple PAVM

Simple PAVM: Coil Embolized

(Left) *A selective 6-Fr sheath was positioned into the arterial feeder* ➡ *of an AVM 1-3 cm proximal to the nidus* ⇨*. Note the draining vein* ⤴ *of the PAVM.* **(Right)** *The right lower lobe AVM has been occluded by deploying a 6-mm Amplatzer occluder device* ➡ *into the feeding artery. Occlusion is confirmed with a right lower lobe DSA obtained via a 6-Fr long sheath* ⤴.



Simple PAVM

Simple PAVM: Amplatzer Plug Embolized

Pulmonary Arteries: Exclusion (Pulmonary AVM)

TERMINOLOGY

Definitions

- **Pulmonary arteriovenous malformation (PAVM)**: High-flow, low-resistance direct fistulous communication between pulmonary artery and vein
    - Causes right-to-left shunt
        - May be asymptomatic if small
        - May be symptomatic if larger
            - Pulmonary-related symptoms may include dyspnea, cyanosis, hemoptysis, polycythemia
            - PAVMs potential source for paradoxical emboli; can cause stroke, brain abscess
    - PAVM classification
        - Simple PAVM: Single segmental feeding artery
            - May have multiple subsegmental arterial branches to malformation
        - Complex PAVM: Multiple segmental feeding arteries perfuse malformation
        - Diffuse PAVMs: Hundreds of malformations (or more)
            - Estimated to occur in 5% of PAVM patients
            - May require lung transplant for treatment
    - 80-90% occur in patients with hereditary hemorrhagic telangiectasia
    - Acquired causes include trauma, malignancy, hepatopulmonary syndrome, and cardiac surgery
- **Hereditary hemorrhagic telangiectasia (HHT)**: Autosomal dominant genetic abnormality causing development of arteriovenous shunts
    - a.k.a. Osler-Weber-Rendu syndrome
    - May affect nasal mucosa, skin, gastrointestinal tract, lung, central nervous system
        - Lung manifestations: PAVMs
            - PAVMs occur in 15-25% of patients with HHT
            - 60% of HHT patients who have PAVMs have multiple lesions
            - Untreated PAVMs can predispose patients to increased risk for cerebral abscess, transient ischemic attack, stroke
            - Screen for PAVMs using transthoracic agitated saline echocardiography bubble study
            - Can also screen using CTA (include liver to assess for liver AVM)
    - 4 major diagnostic criteria for HHT
        - Epistaxis (main presenting symptom in HHT)
            - Measured by Epistaxis Severity Score
        - Telangiectasias/arteriovenous shunts
        - Visceral lesions
        - Family history of 1st-degree relative with HHT
    - HHT likelihood by number of criteria present
        - 3 criteria present: Definite
        - 2 criteria present: Possible
        - 1 criterion present: Unlikely

PREPROCEDURE

Indications

- Transcatheter embolization of PAVMs
    - PAVM
        - Lesions with feeding arteries ≥ 2 mm in diameter (historically > 3)
            - Should be routinely embolized based on size
            - 30-40% of patients with feeding vessels > 3 mm present with transient ischemic attack, stroke, or brain abscess
            - Risk of paradoxical embolus if untreated
        - Lesions with feeding arteries < 3 mm (microscopic PAVMs)
            - Follow-up in 3-5 years with CT
            - Antibiotic prophylaxis for dental procedures and filters for IVs
- Work-up
    - Pulmonary CTA
    - Electrocardiogram to assess for left bundle branch block
    - Standard preprocedure labs (creatinine, coagulants, platelets)

Contraindications

- Any pulmonary arteriography: Relative contraindications
    - Left bundle branch block
        - Temporary pacer must be employed to prevent complete heart block
    - Contrast allergy
    - Renal insufficiency

Preprocedure Imaging

- CECT
    - Localizes abnormality; delineates vascular supply

Getting Started

- Things to check
    - Clinical history and physical examination
        - Procedure indications
            - Determine appropriateness and safety of intervention
        - Clinical status of patient
            - Patient's ability to tolerate procedure
            - Baseline assessment of neurologic status before PAVM embolization
        - Current medications
            - Any anticoagulants, antiplatelet agents, oral hypoglycemic agents, antihypertensives
    - Allergies
        - Iodinated contrast allergy
        - Nickel allergy
    - Electrocardiogram
        - Evaluate for left bundle branch block
            - If left bundle branch block is present, float temporary pacemaker
    - Laboratory parameters
        - Electrolytes, glomerular filtration rate (eGFR)
            - Prefer normal Cr; eGFR > 60
        - CBC
            - Platelet count > 50,000/μL
        - Coagulation profile; correct any coagulopathy
            - INR ≤ 1.7
            - Normal PT, partial PTT
    - Obtain written informed procedural consent
- Medications
    - Conscious sedation agents
        - Fentanyl/midazolam typically used
    - 1-2% lidocaine local anesthesia

  - Heparin
    - Consider heparin if patient has low incidence of epistaxis
    - Consider partial dose (50-70 U/kg)
    - Antibiotic prophylaxis; cephalosporin (typically)
- Equipment list
  - Vascular access sheath
    - Permits catheter exchanges as necessary
      - Reduces local complications at access site
    - 5- to 6-Fr diameter typically used
  - Guidewires
    - Initial "starting" 0.035" guidewire (3-J tip)
      - 0.035", 145-cm Bentson guidewire
    - Angled or straight-tipped hydrophilic guidewire
      - Useful for selective arterial catheterization
    - Tip-deflecting guidewire
      - Used with pigtail/Grollman catheter to negotiate cardiac chambers/pulmonary arteries
    - Stiff guidewire: Amplatz or Rosen
    - Microwire for use with coaxial microcatheter
    - 0.14", 300-cm ATW Marker Wire
  - Catheters
    - Flush catheter for pulmonary DSA
      - e.g., Grollman, pigtail, Omni Flush, 7-Fr Van Amman diagnostic catheter
    - 5-Fr selective catheters (various designs)
      - e.g., Davis, Cobra
    - White Lumax system (Cook; Bloomington, IN)
      - 7-Fr guiding sheath
      - 5-Fr angled-tip selective catheter
      - 8-Fr, 90-cm MPA catheter
      - 9-Fr, 11-cm Introducer Sheath
    - 5-Fr Micropuncture set
  - Microcatheter
    - Various proprietary designs
    - Used coaxially for superselective DSA/treatment
  - Embolization equipment
    - Amplatzer II or IV vascular plug (St. Jude Medical; North Plymouth, MN)
      - Varying sizes/configurations; delivered via guiding sheath placed in target artery
      - Mechanically occludes target vessel in similar manner to coil embolization
    - Embolization coils (various proprietary designs)
      - Detachable 0.035" or 0.018" embolization coils
    - Micro Vascular Plug (MVP) (Reverse Medical Corporation; Irvine, CA)
      - Delivered using microcatheter 2.8-Fr Progreat microcatheter (Terumo Corporation; Tokyo, Japan)
  - Fluid/air filter
    - 0.2 μm to prevent air bubbles from passing through PAVM
    - 7" Microbore Extension Set
  - Adapters
    - Tuohy-Borst Adapter
    - Flow switches

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Transfemoral venous access (right typically)
  - Brachial/jugular access if femoral vein thrombosis

Procedure Steps

- **General**
  - Sterilely prepare/drape intended access site
    - If electrocardiogram shows left bundle branch block, float temporary pacemaker
    - Use 0.2-μm air filter to remove air bubbles throughout procedure
  - Administer 1% lidocaine local anesthesia
  - Obtain venous access; place access sheath
    - All catheters placed into venous side must be under water
    - Double flush all catheters to avoid air bubbles and clots
    - 4 fusion pumps are attached to Fluid/Air 7" Microbore Extension Set air filter using Tuohy-Borst Y-adapter to remove air bubbles from catheter
    - No vacuum on catheter
  - Administer IV heparin: 3,000- to 5,000-U bolus
  - Introduce catheter (e.g., Grollman) over guidewire
  - Advance Grollman catheter into right atrium (RA)
    - Reposition catheter/guidewire if arrhythmia
  - Once catheter tip in right ventricle, must redirect into pulmonary outflow tract/main pulmonary artery
    - If using tip-deflecting guidewire, relax tension
      - Gently rotate catheter, direct cranially to enter outflow tract and main pulmonary artery
  - Measure pulmonary artery pressure; assess for pulmonary artery hypertension
  - Inject nonionic contrast; obtain DSA images
    - Right/left pulmonary artery injection parameters
      - 20-22 mL/s flow rate; 40- to 44-mL volume
      - 15 mL/s flow rate; 30-mL volume without nonionic contrast
      - Decrease volume if significant pulmonary artery hypertension present
    - Projections for image acquisitions
      - Ipsilateral anterior/posterior obliques at 45-60°
      - AP/superselective/magnified views as needed
      - 3D DSA at low contrast
- Embolization of PAVM
  - Use Lumax guiding wire
  - Procedure is completed entirely under water to avoid air clots
    - 4 fusion pumps are attached to Fluid/Air 7" Microbore Extension Set air filter using Tuohy-Borst Y-adapter to remove air bubbles from catheter
  - Double flush every catheter
  - Access right common femoral vein
    - Micropuncture exchange over 0.035", 145-cm Bentson guidewire
  - 9-Fr, 11-cm Introducer Sheath is placed
  - Advance 7-Fr Grollman or 7-Fr Van Aman diagnostic catheter through Introducer Sheath from RA to pulmonary artery

  - Transduce pressure across RA, right ventricle, and pulmonary artery
    - Unilateral pulmonary arteriogram: 10 cc/s for 20-cc total volume, each side
  - Exchange length of Rosen wire for stability
  - Insert 7-Fr Grollman into pulmonary artery
  - Pull out Rosen wire and exchange for Pulmonary Lumax White Guide catheter set (Lumax in 6-Fr set)
  - Select guide catheter
  - Obtain DSA with hand-injected contrast
  - Microcatheter with high-flow MVP > 5 mm and regular MVP (1-3 mm)
    - Can use sizing wire or measure off of angiogram
  - Measure diameter of AVM
    - Coil/plug size and type important consideration
      - Undersized device could embolize distally
      - Can use detachable coils: More precise control
      - Oversize by 20-50% relative to feeding vessel for all occlusion methods except for MVP; match vessel size for MVP
  - Proceed with embolization of target
    - Embolize within 1 cm of nidus
    - Anchor technique of embolization
      - Should not place coil directly into PAVM due to risk of paradoxical embolization of coil
      - Place tip of coil in small side branch proximal to target; allow to prolapse into feeding vessel
      - Ensure that coils are tight and dense to prevent recanalization
    - Amplatzer plug occluding device placement
      - Place appropriately sized sheath in feeding vessel
      - Introduce Amplatzer device via sheath; position in feeding vessel proximal to target
      - Confirm position with contrast injection
      - Deploy device by retracting sheath
    - MVP occluding device placement
      - Advance MVP-5 system into feeding artery
      - Unsheath microvascular plug to occlude target vessel
      - Confirm position by using selective angiogram using 1 mL of contrast injected via Y-connector
      - Deploy MVP using detachment system
      - Final angiogram after deployment to confirm position and occlusion
    - Confirm satisfactory embolization result with DSA

Alternative Procedures/Therapies

- Surgical lobectomy, pneumonectomy

POST PROCEDURE

Postprocedure Imaging

- Lateral and frontal chest x-ray to establish new baseline
- Chest CT 1-3 months after treatment to reestablish baseline
- Follow-up after AVM embolization every 3-5 years

OUTCOMES

Complications

- Most feared complication(s)
  - **General**
    - Cardiac arrhythmia
    - Cardiac chamber perforation
  - **PAVM embolization**
    - Paradoxical embolization of embolic agent/coil loss/coil migration
      - Can migrate into systemic arterial circulation
      - Can usually be successfully retrieved with snare
    - Intraprocedural iatrogenic air embolization (< 5%)
      - May enter left coronary artery (anteriorly located), causing chest pain or bradycardia
      - May enter cerebral circulation, leading to stroke
    - Intraprocedural iatrogenic thrombus embolization
- Delayed complication(s)
  - **PAVM embolization**
    - Self-limited postembolization pleurisy: 14-31%
      - Usually occurs 48 hours or later
      - May also occur as delayed event (2-4 months); may have severe pleurisy and fever
    - Pulmonary artery hypertension (rare)

Expected Outcomes

- > 95% initial success rate in PAVM treatment following transcatheter embolization
- Recanalization of embolized segments reported in up to 25% of embolizations, usually when coils are deployed

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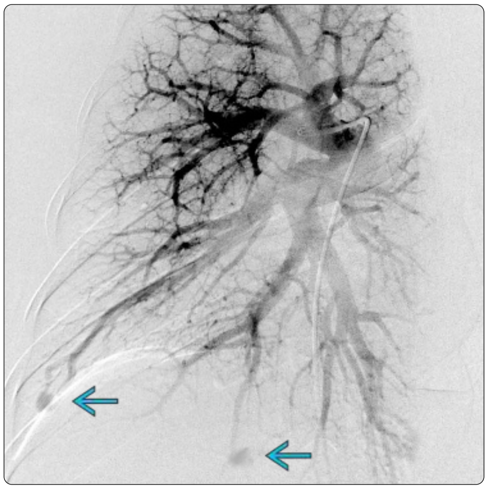
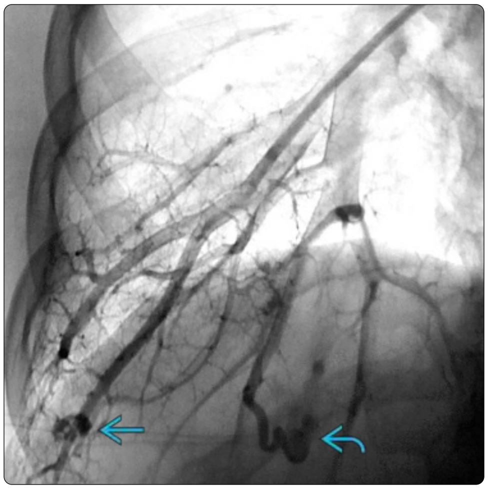
(Left) *Right pulmonary artery DSA in a patient with HHT shows 2 separate PAVMs → in the right lung base. 80-90% of PAVMs occur in patients with HHT.* **(Right)** *Magnified native DSA better demonstrates the lateral → and medial ↷ AVMs. PAVMs should be embolized when the feeding artery diameter is ≥ 3 mm, as there is a high risk of paradoxical embolus, which may result in transient ischemic attacks, stroke, or brain abscess.*

Hereditary Hemorrhagic Telangiectasia (Right Pulmonary Artery DSA)

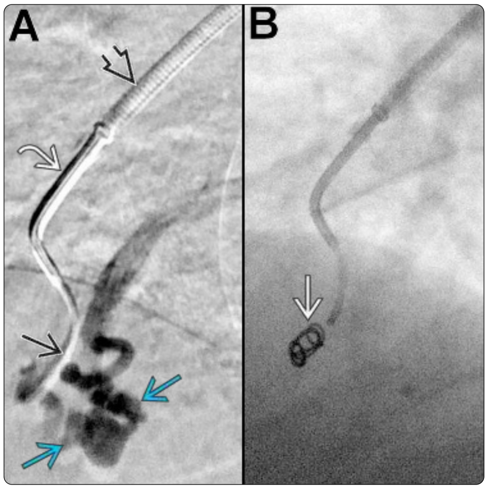


Hereditary Hemorrhagic Telangiectasia (Magnified DSA)

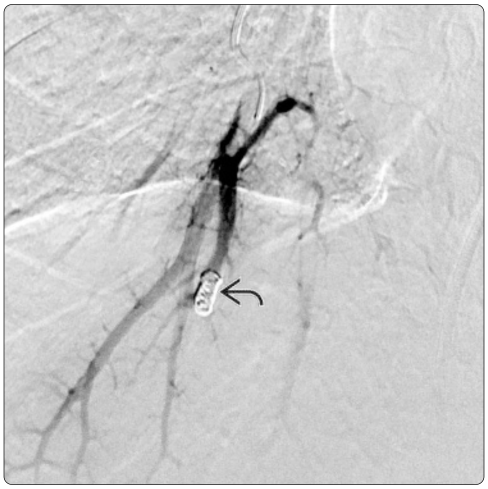


(Left) *(A) Superselective DSA of the medial AVM → was obtained via a coaxial microcatheter ⇨ that was introduced through a 5-Fr Kumpe catheter ➡. A guiding sheath ↷ was used to provide stability. (B) Embolization coils ➡ were placed in the feeding artery and were oversized by 20-25% relative to the feeding vessel, as an undersized coil could potentially embolize distally.* **(Right)** *Postembolization DSA via the coaxial microcatheter shows that the coils ↷ are in a satisfactory position and have occluded the PAVM.*

Hereditary Hemorrhagic Telangiectasia: Transcatheter Coil Embolization

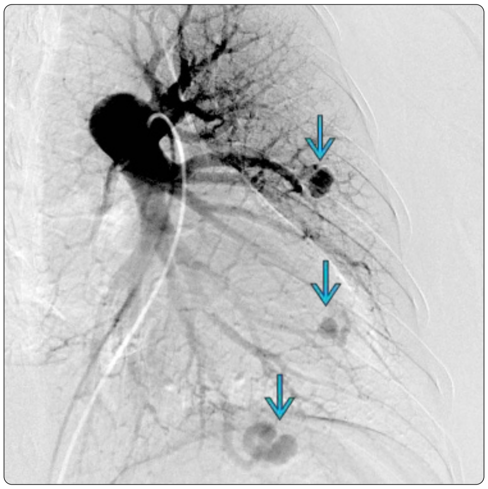


Hereditary Hemorrhagic Telangiectasia: Post Embolization (Subsegmental DSA)

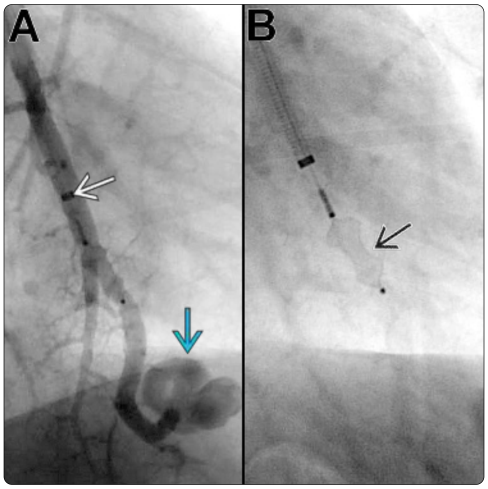


(Left) *Left pulmonary artery DSA in the same patient shows multiple additional PAVMs →. Only 15-25% of HHT patients have PAVMs; when present, they are most often multiple.* **(Right)** *(A) Spot radiograph shows that a guiding sheath ➡ has been placed in the subsegmental artery feeding the basilar AVM and contrast has opacified the malformation →. (B) An Amplatzer plug occluder ⇨ has been placed in the artery feeding the AVM and will be deployed in this position. This is an effective alternative to coil embolization.*

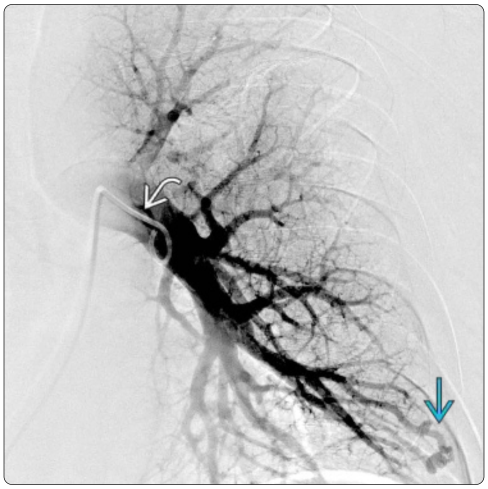
Hereditary Hemorrhagic Telangiectasia (Left Pulmonary Artery DSA)



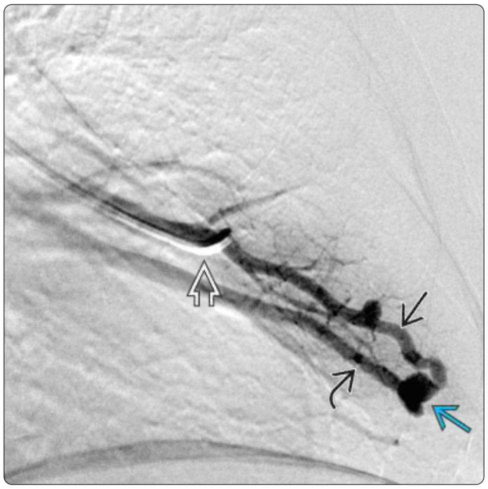
Hereditary Hemorrhagic Telangiectasia: Embolization With Amplatzer Plug



Solitary PAVM (Left Pulmonary Artery DSA)

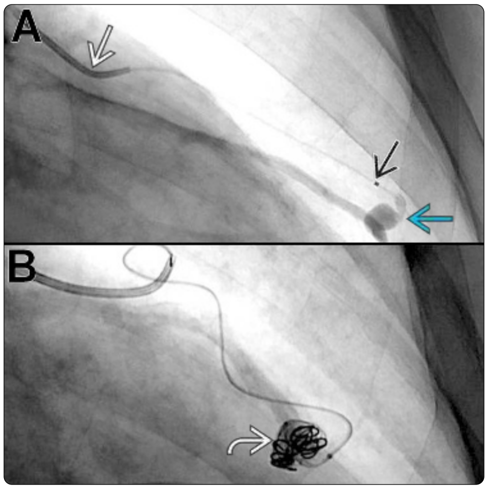


Solitary Pulmonary AVM (Superselective Subsegmental DSA)

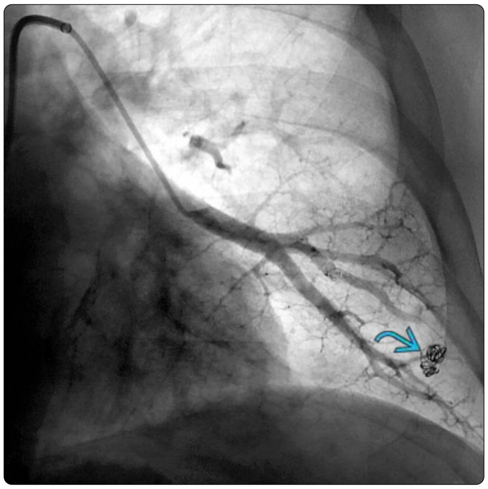


(Left) *Left pulmonary artery DSA, obtained via a pigtail catheter ↪, demonstrates a solitary pulmonary AVM → in the lateral aspect of the left lung base.* **(Right)** *A multipurpose angled catheter ➡ has been selectively introduced into the subsegmental pulmonary artery supplying the AVM. This is a simple AVM →, which has a direct fistulous communication between a single feeding pulmonary artery → and a single draining vein ↪.*

Solitary PAVM: Transcatheter Coil Embolization

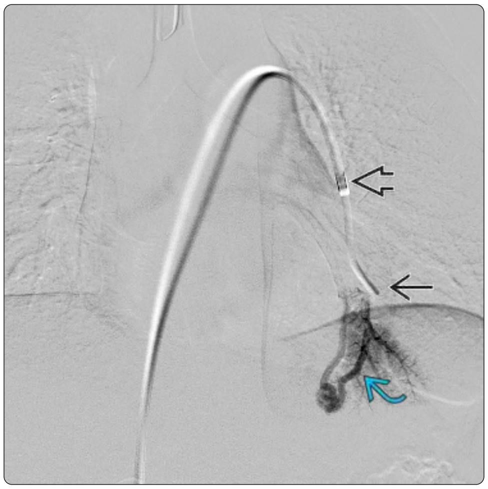


Solitary Pulmonary AVM (Final Pulmonary Arteriogram)

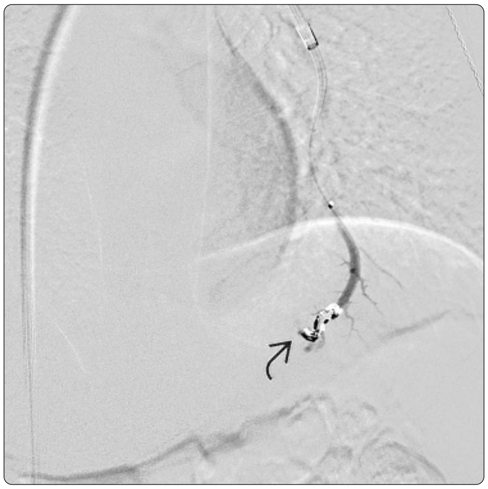


(Left) *(A) A spot radiograph shows that a coaxial microcatheter → has been introduced distally in the AVM via the angled catheter ➡. Fistulous communication → and draining vein are seen. (B) Detachable embolization coils ↪ have been placed directly in the AVM, a suboptimal embolization method, as it could allow paradoxical embolization of the coils into the systemic circulation.* **(Right)** *A segmental native arteriogram shows the embolization coils ↪ in place and no filling of the AVM or draining vein.*

Single PAVM: Pre-Embolization (DSA)



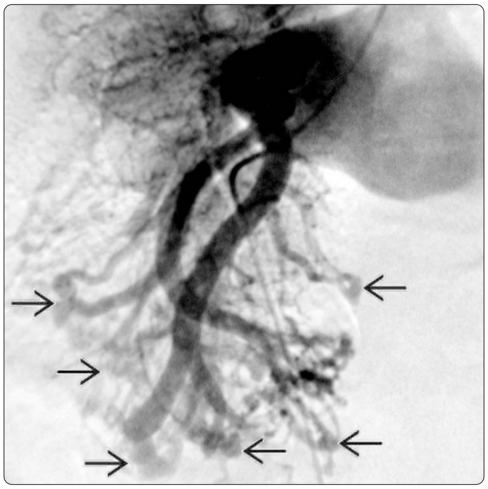
Single PAVM: Post Embolization (DSA)



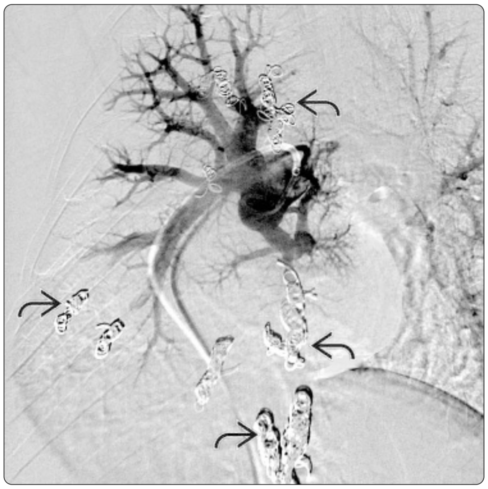
(Left) *A simple PAVM is highlighted on a DSA obtained via a coaxial 5-Fr catheter → advanced through a guidesheath ⇨. The 5-Fr catheter is near the feeding artery ↪. The catheter may be further advanced, but coaxial advancement of a microcatheter into the feeding artery will likely allow more exact embolization.* **(Right)** *Coils ↪ were deployed via a microcatheter, successfully occluding the feeding vessels to the PAVM.*

(Left) *Diffuse PAVMs → occur in ~ 5% of patients with HHT, as seen in this DSA of the right lower lobe pulmonary arterial circulation.* **(Right)** *After multiple treatment sessions, this patient with HHT and diffuse PAVMs shows scattered groups of embolization coils ⤴ occluding the various malformations.*

Diffuse PAVMs (Right Pulmonary Artery DSA)

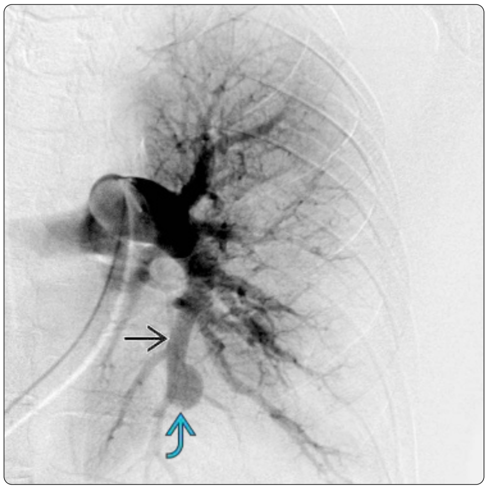


Diffuse PAVMs: Post Embolization (Right Pulmonary DSA)

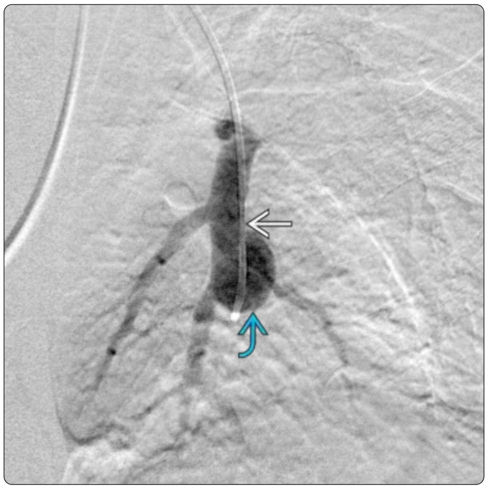


(Left) *A large pulmonary artery pseudoaneurysm ⤴ is seen arising from the left posterior basal segmental pulmonary artery →. The patient is a known intravenous drug abuser with multiple pulmonary abscesses.* **(Right)** *A multipurpose angled catheter ➔ was used to selectively catheterize the left lower lobe segmental pulmonary artery ⤴. DSA imaging was obtained in order to delineate the vascular anatomy associated with the pseudoaneurysm in preparation for transcatheter coil embolization.*

Pulmonary Artery Pseudoaneurysm (Left Pulmonary Artery DSA)

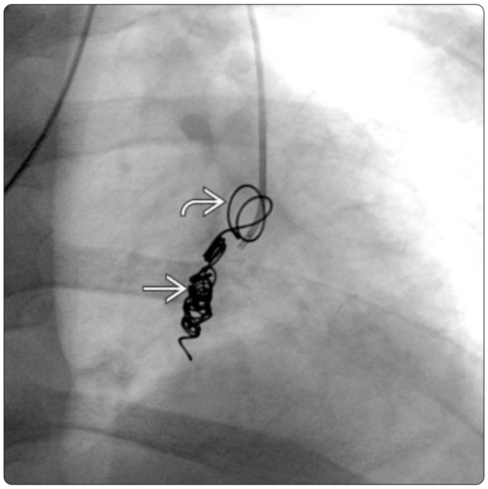


Pulmonary Artery Pseudoaneurysm (Superselective Pulmonary Artery DSA)

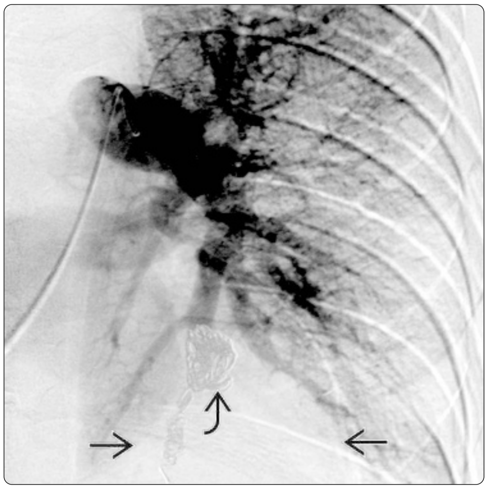


(Left) *The catheter was advanced into a subsegmental arterial branch arising from the pseudoaneurysm, so the initially placed embolization coils ➔ would occlude the vessel beyond the abnormality. The coils were then extended proximally ➔ into the pseudoaneurysm.* **(Right)** *After coil embolization, a repeat left pulmonary artery DSA was obtained, confirming that the pseudoaneurysm was occluded by the coils ⤴. A wedge-shaped area of nonperfusion → represents the occluded vascular territory distal to the pseudoaneurysm.*

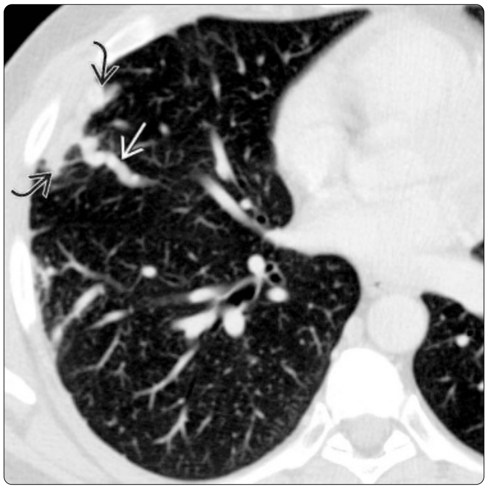
Pulmonary Artery Pseudoaneurysm: Transcatheter Coil Embolization



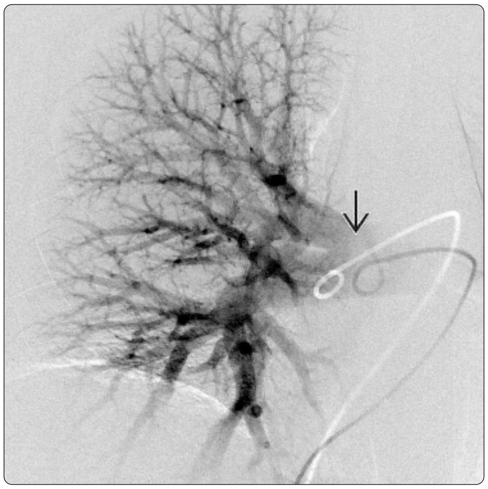
Pulmonary Artery Pseudoaneurysm: Post Embolization (Final DSA)



PAVM Misdiagnosis: Initial Evaluation (CECT)

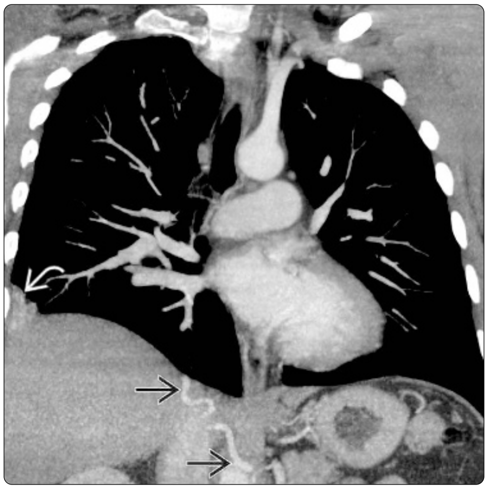


PAVM Misdiagnosis (DSA)

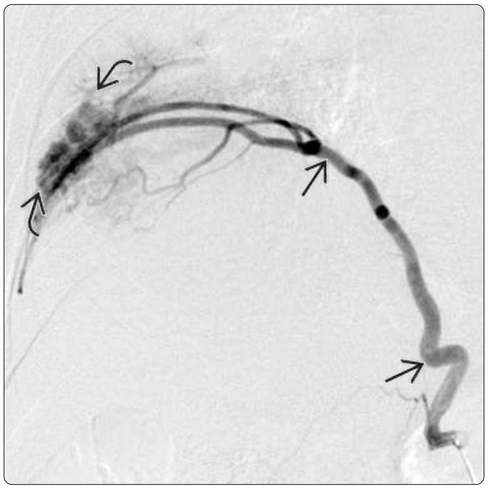


(Left) *A serpiginous vessel ➡ courses to a nodular pleural-based density ↪ in the anterolateral aspect of the right lung base, which was felt to represent a PAVM. As there was a vague past history of epistaxis, HHT was suspected. However, the patient had also undergone prior resection of a right chest wall schwannoma.* **(Right)** *A right pulmonary artery → DSA was performed in preparation for a planned embolization of the PAVM. However, despite multiple projections, no AVM was identified.*

PAVM Misdiagnosis (Repeat CECT Evaluation)

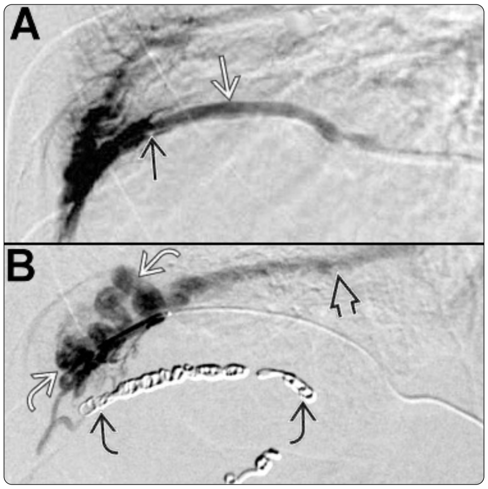


PAVM Misdiagnosis (Right Inferior Phrenic Artery DSA)

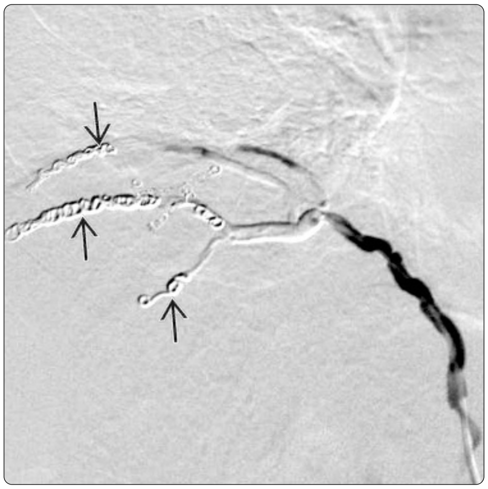


(Left) *Repeat CECT of the chest and upper abdomen was obtained after the pulmonary DSA. Coronal reconstruction shows an enlarged, tortuous right inferior phrenic artery → coursing toward the pleural-based nodular abnormality ➦.* **(Right)** *Subsequently, DSA revealed a hypertrophied inferior phrenic artery → supplying a vascular malformation ↪ corresponding to the pleural-based abnormality that was originally felt to be a PAVM. Thus, this is actually a systemic arterial to pulmonary venous malformation.*

PAVM Misdiagnosis: Transcatheter Coil Embolization



PAVM Misdiagnosis: Post Embolization (DSA)



(Left) *(A) DSA via a microcatheter → in the more inferior division ➡ of the phrenic artery shows that this contributes to only a portion of the malformation. (B) After placing embolization coils ↪ in the inferior division, the microcatheter was introduced into the superior division, where DSA shows the large malformation ➦ and draining vein ⇨.* **(Right)** *Occlusion of the malformation required coil embolization of multiple phrenic artery branches. The postembolization DSA shows that the coils → have eliminated flow to the AVM.*

Bronchial Artery Embolization

KEY FACTS

TERMINOLOGY

- **Hemoptysis**: Coughing up of blood from bronchi, larynx, trachea, lungs
    - Often due to infection, mucosal inflammation, malignancy
    - Majority of patients (90-95%) present with small-volume hemoptysis not requiring invasive therapy
- **Massive hemoptysis**: > 300 mL blood in 24 hours
    - Most commonly due to bronchial artery (BA) hypertrophy secondary to chronic lung inflammation or chronic pulmonary artery vasoconstriction or obstruction
    - Erosion of mucosa overlying hypertrophied BAs leads to massive bleeding causing asphyxiation

PROCEDURE

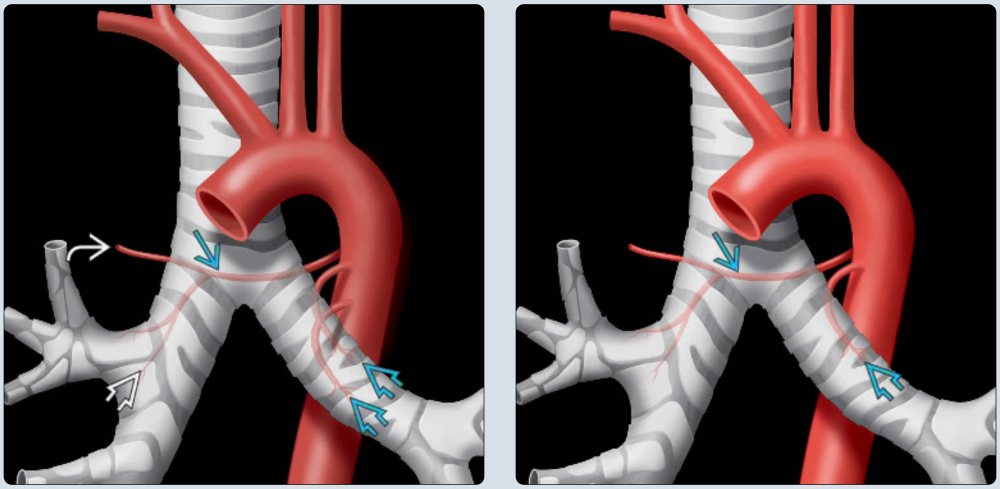
- Preprocedure CTA ± bronchoscopy to determine laterality, localize hypertrophied BAs, exclude pulmonary artery source
- Descending thoracic aortogram with flush catheter to identify origin, number, and course of BAs
- Selectively catheterize BA with 5-Fr catheter and perform arteriogram
- Coaxially advance microcatheter to limit nontarget embolization (particularly to anterior spinal artery)
- Embolize to near stasis with particulates (> 350 μm diameter)

POST PROCEDURE

- If continued hemoptysis, repeat BA embolization (BAE) or search for alternative nonbronchial source, such as pulmonary artery, may be necessary
    - BAE controls bleeding, does not treat underlying causative pathology

OUTCOMES

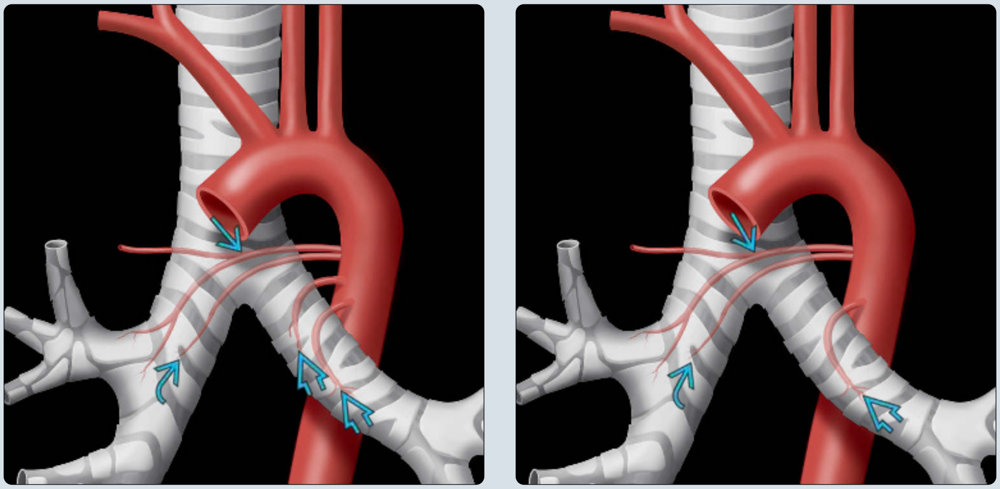
- Recurrence rates 2-27% at 1 month, 10-52% at 46 months
- Most feared complication: Lower extremity paralysis due to nontarget embolization of anterior spinal artery



Cauldwell Orthotopic Bronchial Artery Branching: Type 1

Cauldwell Orthotopic Bronchial Artery Branching: Type 2

(Left) *Graphic shows a right intercostobronchial trunk (intercosto ↪ bronchial ⇨ trunk →) and 2 left bronchial arteries ⇨ arising from the descending thoracic aorta at the T5-6 level. The bronchial arteries parallel the airways, entering the lungs at the hilum.* **(Right)** *Graphic shows 1 right intercostobronchial trunk → and 1 left bronchial artery ⇨ arising from the descending thoracic aorta. Again, the bronchial arteries parallel the airways, entering the lungs at the hilum.*



Cauldwell Orthotopic Bronchial Artery Branching: Type 3

Cauldwell Orthotopic Bronchial Artery Branching: Type 4

(Left) *Graphic shows 1 right intercostobronchial trunk →, 1 right bronchial artery ↪, and 2 left bronchial arteries ⇨ arising from the descending thoracic aorta.* **(Right)** *Graphic shows 1 right intercostobronchial trunk →, 1 right bronchial artery ↪, and 1 left bronchial artery ⇨ arising from the descending thoracic aorta.*

TERMINOLOGY

Definitions

- **Hemoptysis**: Coughing up of blood arising from lungs or airways
  - Typically caused by erosion/bleeding of overlying airway mucosa or rupture of hypertrophied bronchial arteries
    - Often triggered by infection, mucosal inflammation, or malignancy
    - Most patients (90-95%) present with small-volume hemoptysis not requiring invasive therapy
  - Classified as massive, moderate, or mild
- **Massive hemoptysis**
  - Varied definitions
    - Most common: > 300 mL blood in 24 hours
    - Massive = potentially life-threatening
    - Patients with poor underlying ventilatory reserve may require less blood to inhibit adequate ventilation
  - Potential sources: Generally arterial source due to systemic vascular pressure
    - Bronchial artery (90%)
      - ☐ Localized bronchial artery proliferation & hypertrophy in response to chronic pulmonary artery vasoconstriction (from hypoxia), obstruction, or stimulation from chronic inflammation (rubor)
    - Nonbronchial systemic artery (5%)
      - ☐ Common vessels include intercostal arteries, branches of brachiocephalic/subclavian arteries, inferior phrenic arteries
      - ☐ Chronic inflammation/hyperemia can lead to collateral recruitment from systemic arteries, particularly when disease involves pleura/chest wall
    - Pulmonary artery (5%)
      - ☐ Low pressure of pulmonary artery makes it less common cause of massive hemoptysis
      - ☐ Consider with history of trauma/intervention or cavitary lesion
      - ☐ CTA often shows suggestive findings such as PA aneurysm/pseudoaneurysm or branch along inner wall of cavity
  - Disease etiologies of massive hemoptysis
    - Common causes of bronchial/systemic artery source
      - ☐ Chronic infections: Tuberculosis (most common world wide), fungal, chronic pneumonia, abscess
      - ☐ Chronic inflammatory states: Cystic fibrosis, sarcoidosis, Wegener granulomatosis
      - ☐ Acquired/congenital pulmonary stenosis/occlusion
      - ☐ Malignancy
    - Common causes of pulmonary artery source
      - ☐ Rasmussen aneurysms, septic emboli, necrotizing pneumonia
      - ☐ Iatrogenic/traumatic pseudoaneurysm
      - ☐ Cavitary malignancy
      - ☐ Pulmonary arteriovenous malformation
- **Moderate hemoptysis**
  - Blood loss > 100 mL/day over 3 days per week
- **Bronchial artery anatomy**: Many known anatomic variations in arterial number, origin, course
  - By definition bronchial arteries, even when ectopic in origin, parallel central airways and enter lungs at hilum
  - Typically <1.5 mm in diameter at origin decreasing to 0.5 mm when entering bronchopulmonary segment
  - Branch with airways and peripherally supply submucosal plexus in close proximity to airway lumen, with anastomotic connections to pulmonary arteries (bronchopulmonary anastomosis)
    - Provide nutrient supply to multiple structures
      - ☐ Bronchi
      - ☐ Diaphragmatic/mediastinal visceral pleura
      - ☐ Subcarinal lymph nodes
      - ☐ Middle 1/3 of esophagus
      - ☐ Dorsal/ventral nerve roots (radicular arteries)
      - ☐ Vasa vasorum of aorta, pulmonary arteries/veins
      - ☐ Spinal cord (medullary arteries): "Hairpin" with supply to anterior spinal artery; often arises from right intercostobronchial trunk (RICBT)
- Normal/orthotopic origin of bronchial arteries (64% of patients on CTA)
  - Origin from descending thoracic aorta between T5-T6 within 1 cm of where left bronchus crosses aorta
    - RICBT usually arises from medial to posteromedial aorta similar in origin to intercostal artery
    - Right bronchial artery often arises from medial to anteromedial aorta whereas left bronchial artery generally arises anteriorly
  - Cauldwell patterns of orthotopic bronchial artery branching (based on anatomic studies of 150 cadavers)
    - Type 1: RICBT/2 left bronchial arteries (41%)
    - Type 2: RICBT/1 left bronchial artery (21%)
    - Type 3: RICBT/1 right bronchial artery/2 left bronchial arteries (21%)
    - Type 4: RICBT/1 right bronchial artery/1 left bronchial artery (10%)
    - Types 5-9: Varying configurations and number of right and left bronchial arteries (8%)
- Ectopic/aberrant origin of bronchial arteries (36% of patients on CTA)
  - BA origin not at T5-T6 level; however, entry into lung is still along major bronchi
    - Undersurface of aortic arch (74%)
    - Branches of brachiocephalic/subclavian artery (10.5%): Internal mammary artery, thyrocervical trunk, subclavian artery, costocervical trunk
    - Descending aorta or its branches (8.5%)

PREPROCEDURE

Indications

- Massive hemoptysis
  - Emergent bronchial artery embolization (BAE)
    - 1st line of therapy for bleeding control
    - Temporizing or palliative measure
  - Conservative treatment has high (50-100%) mortality
  - Definitive/curative treatment requires surgical &/or medical therapy to treat underlying lung disease
- Moderate hemoptysis, recurrent bouts
  - Urgent BAE indicated for bleeding control
- Mild hemoptysis
  - Chronic or slowly increasing episodes resistant to conservative therapy
  - Any hemoptysis compromising airway/ventilation

Contraindications

- Nonbronchial artery hemoptysis source
    - Nonbronchial systemic collateral or pulmonary artery
    - Upper airway source
- Usual contraindications to angiography

Preprocedure Imaging

- CTA of chest
    - Commonly becoming standard of care prior to BAE
        - Reduces rate of BAE failures, surgical interventions
    - Review extent & location of underlying pathology
        - Assess for focal or unilateral processes
        - Unilateral ground-glass opacity may suggest side of bleeding
    - Review anatomy of hypertrophied bronchial arteries
        - Orthotopic & ectopic bronchial artery size, number, and origins
    - Review anatomy of nonbronchial systemic arteries
        - Pleural thickening or hypertrophied tortuous extrapleural vessels may indicate nonbronchial systemic arterial supply
        - Nonbronchial systemic arteries do not enter lung within hila adjacent to bronchi
    - Review for evidence of pulmonary artery source
        - More common with cavitary lung lesions
        - CTA often shows suggestive findings such as PA aneurysm/pseudoaneurysm or branch along inner wall of cavity
- Bronchoscopy
    - Useful in identifying bleeding side
        - Evaluates upper airway & central bronchi
    - Locoregional therapy may be possible
        - Laser coagulation, thrombin administration
        - Infusion of vasoactive agents

Getting Started

- Things to check
    - Clinical history and physical examination
        - Details of underlying pulmonary pathology (including etiology, laterality, and focality)
        - Localizing symptoms (e.g., "gurgling" sensation from bleeding lung)
        - Known history of recent trauma/lung procedure or pulmonary artery catheterization/intervention
        - Prior history of massive hemoptysis and BAE
        - Current medications
            - Particularly anticoagulants, antiplatelet agents, oral hypoglycemic agents (such as metformin), antihypertensives
    - Airway status
        - Baseline and current respiratory status; need for ventilation optimization/protection
        - Intubate if any indication of airway compromise
            - Prevents lung drowning by blood in airways
    - Allergies
        - Particularly to latex, iodinated contrast, lidocaine, sedation medications, and chlorhexidine
    - Laboratory parameters
        - Electrolytes, glomerular filtration rate (eGFR)
            - Prefer normal Cr; eGFR > 60
        - Complete blood count (CBC)
            - Platelet count > 50,000/μL
        - Coagulation profile
            - International normalized ratio (INR) ≤ 1.5
    - Consent, procedure specific
        - Discuss potential effects of nontarget embolization including paralysis, contrast-induced nephropathy, incomplete treatment/recurrent hemoptysis (BAE does not treat underlying causative pathology)
- Equipment list
    - Catheters
        - Angiographic flush catheter
            - Pigtail flush catheter
        - Reverse-curve selective catheters
            - Mikaelson, Simmons-1, SOS selective
        - Forward-engaging selective catheters
            - Cobra, LEV1, Headhunter
        - Hi-flow microcatheter
    - Vascular sheath
        - Long (45-50 cm) 5-/6-Fr straight sheath is very helpful for catheter stability and catheterization of tortuous bronchial arteries
        - Useful for facilitating catheter exchanges in CFA
    - Embolic agents
        - Particles (spherical embolics)
            - Particles > 350 μm in size generally used to decrease risk of passage through microscopic shunts to pulmonary arteries/veins or tiny branches supplying other mediastinal structures
            - Mix embolic agent with contrast; allows visualization during embolization
        - Coils
            - May occasionally be used to divert flow of particulate embolics away from unintended targets (particularly when embolizing nonbronchial systemic arteries)
            - Generally not used for bronchial artery embolization as they embolize proximally and prevent future interventions
            - May be useful if treating aneurysm/pseudoaneurysm of pulmonary artery
        - n-butyl-2-cyanoacrylate (NBCA) "glue" may be more effective embolization agent

PROCEDURE

Procedure Steps

- Review prior CTA/cross-sectional images
    - Determine location/number of hypertrophied BA
- Obtain femoral arterial access; place sheath
    - Long, straight sheath that reaches thoracic aorta can provide helpful stability
- Introduce angiographic flush catheter; position in transverse or descending thoracic aorta
- Perform DSA thoracic angiogram
    - Identifies bronchial artery origins/number/course
        - Demonstrates hypertrophied bronchial arteries
    - May show systemic artery recruitment
        - These may require particle embolization
        - Varied opinions as to whether to embolize recruited systemic vessels routinely or only after BAE failure

  - Aortogram may be unnecessary if detailed vascular anatomy available on prior angiogram or CTA
- Exchange flush catheter for selective catheter
- Selectively catheterize bronchial artery
  - Obtain DSA bronchial arteriogram images
    - Carefully analyze images for arterial anatomy
      - **Exclude possibility of anterior spinal artery (ASA)**
      - ASA arises from RICBT in 5-10% of cases
      - Thin "hairpin" vessel overlying ventral cord on oblique imaging
      - Determine if significant arteriovenous shunting
- Introduce microcatheter through selective catheter
  - Obtain repeat DSA bronchial arteriogram
    - Confirm catheter tip position satisfactory for bronchial artery embolization
      - Distal enough to avoid reflux into thoracic aorta
      - Beyond anterior spinal artery, if present
- Deliver embolic agent through microcatheter
  - Spherical embolics (350-500 μm) favored over coils
    - Coils prohibit future BAE of recurrent hemoptysis
    - Use slow delivery during embolization
      - Avoid reflux/nontarget embolization
    - Embolize to "near-stasis"
      - Minimal antegrade flow in bronchial artery with disappearance of vascular blush
      - Minimizes reflux to arterial origin
- Obtain completion DSA bronchial arteriogram
- Remove catheter/sheath; secure hemostasis

Findings and Reporting

- Angiographic findings seen with hemoptysis
  - Hypertrophic, tortuous bronchial arteries
  - Hypervascularity/neovascularity
  - Bronchial artery pseudoaneurysms
  - Bronchial to pulmonary artery shunting
  - Extravasation (rarely seen)
  - Systemic collateral recruitment
    - Occurs when pathology involves pleura/chest wall
    - Can be significant source for recurrent hemoptysis

POST PROCEDURE

Things to Do

- Detailed neurologic examination
  - Evaluation for nontarget spinal artery embolization
- Postprocedure clinical follow-up
  - If continued hemoptysis, repeat BAE or search for alternative nonbronchial source, such as pulmonary artery, may be necessary
- Appropriate medical/surgical treatment for underlying pulmonary disease causing hemoptysis
  - BAE controls bleeding; does not treat underlying causative pathology

OUTCOMES

Problems

- Recurrent hemoptysis
  - Causes for recurrent hemoptysis/failed embolization
    - Incomplete embolization, vessel recanalization, collateral vessel revascularization, disease progression
  - Higher recurrence rates in certain diseases
    - Aspergillosis, tuberculosis, cystic fibrosis, neoplasm

Complications

- Most feared complication(s)
  - Transverse myelitis, paralysis (1.4-6.5%)
    - From nontarget embolization of anterior spinal artery via medullary artery branch
- Immediate/periprocedural complication(s)
  - Complications of embolization, generally transient
    - Chest pain (24-91%)
      - Often due to embolization of intercostal and chest wall branches
    - Dysphagia (0.7-18%)
      - Due to nontarget embolization of bronchial artery esophageal branches
  - Access site complications
    - Hematoma, pseudoaneurysm, AV fistula
  - Catheterization related vascular injury
    - Bronchial artery dissection, perforation or occlusion
    - Often self-limited or of limited clinical consequence
  - Contrast reaction/nephropathy
- Delayed complication(s)
  - Bronchial necrosis, due to ischemia of bronchi
  - Pulmonary infarction
    - Increased risk with pulmonary artery occlusion or bronchopulmonary arterial shunting

Expected Outcomes

- Technical success (> 90%)
- Clinical success: Hemoptysis control/cessation
  - Recurrence rates at 1 month: 2-27%
  - Long-term recurrence (up to 46 months): 10-52%
    - Repeat BAE can be performed for recurrence

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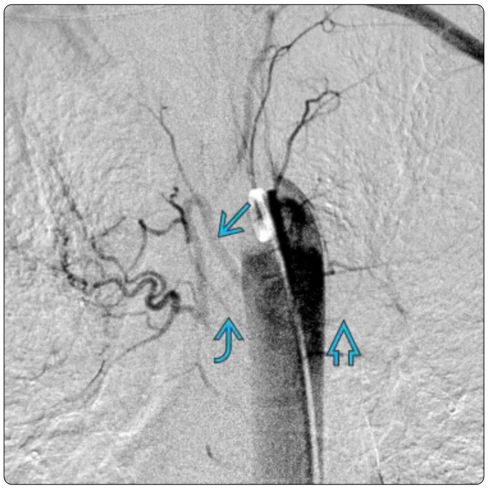
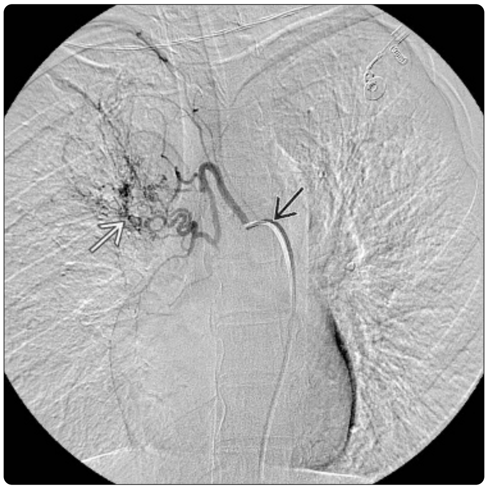
(Left) *Magnified DSA of the descending thoracic aorta using a pigtail catheter better demonstrates a hypertrophied right intercostobronchial trunk* → *. A 2nd right bronchial artery* ↪ *and left bronchial artery are faintly visible* ⇨*.* **(Right)** *Selective arteriogram of the right intercostobronchial trunk with 5-Fr catheter* ➔ *demonstrates hypervascularity within the right lung* ➡*.*

Typical Bronchial Artery Embolization

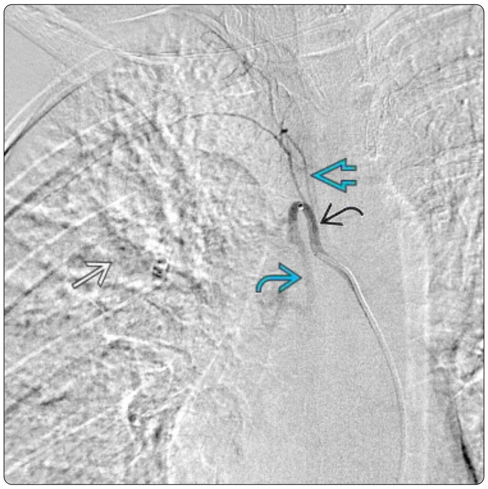


Typical Bronchial Artery Embolization

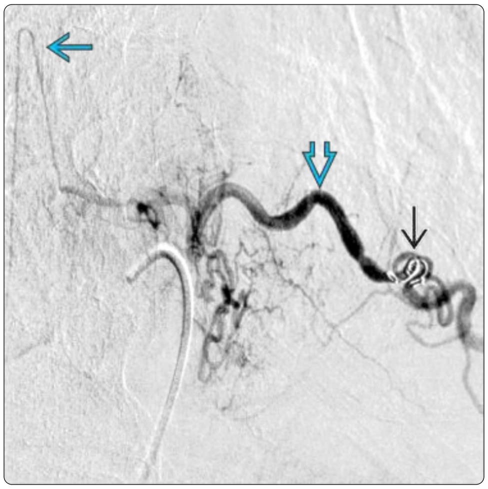


(Left) *Arteriogram of right bronchial artery shows a microcatheter* ➔ *after particulate embolization. There is significantly reduced lung vascularity* ➡ *with near-stasis in the bronchial artery* ↪*. The early branching intercostal arteries remain patent* ⇨*.* **(Right)** *In another patient, this "hairpin" anterior spinal artery* → *became apparent only after coil embolization* ➔ *of a nontarget branch, which altered flow dynamics within the left intercostobronchial artery* ⇨*. The procedure was halted.*

Typical Bronchial Artery Embolization

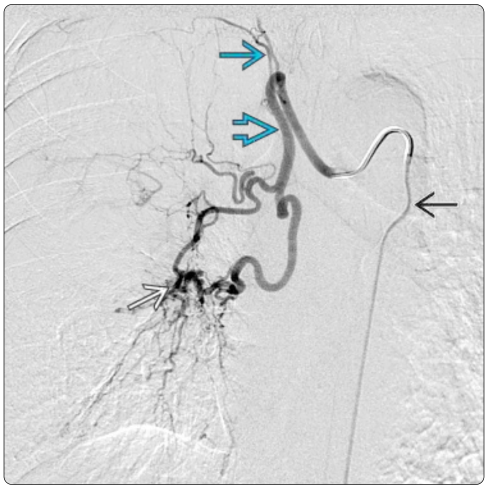


Anterior Spinal Artery (Greater Radicular Artery of Adamkiewicz)

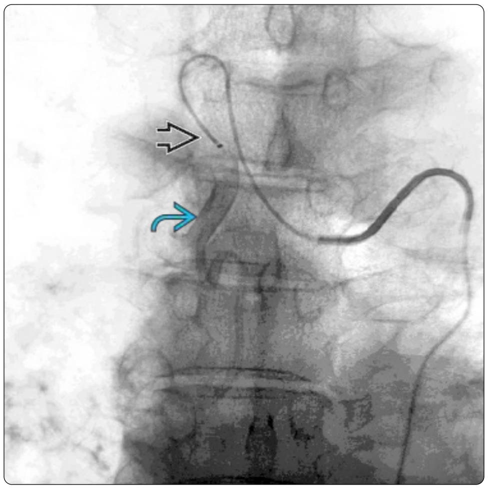


(Left) *Hemoptysis in this patient with cystic fibrosis prompted bronchial artery embolization (BAE). A 5-Fr Mikaelson catheter* ➔ *has engaged a right intercostobronchial artery, highlighting intercostal* → *& bronchial branches* ⇨*. Hypervascularity & vessel tortuosity* ➡ *is seen.* **(Right)** *Image obtained during particle delivery shows a microcatheter* ⇒ *advanced beyond the intercostal branches & antegrade flow* ↪*. With this well-seated catheter location, reflux into nontarget vessels is highly unlikely.*

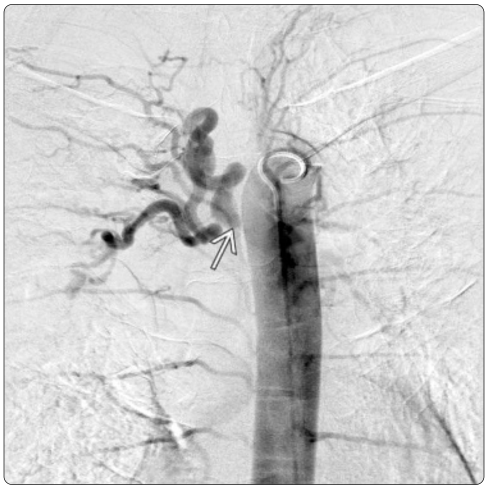
Intercostobronchial Artery Embolization (Diagnostic Arteriogram)



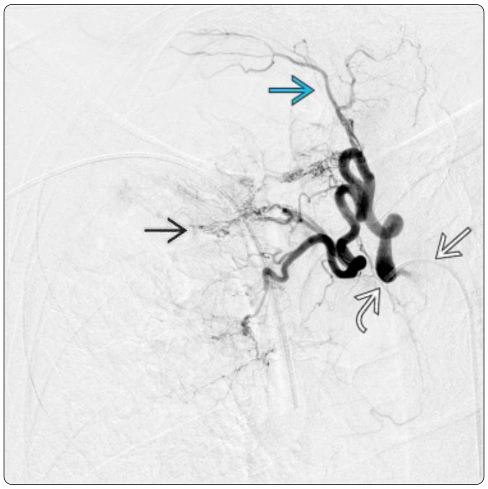
Intercostobronchial Artery Embolization (Particle Delivery via Microcatheter)



Bronchial Artery Embolization Procedure (Descending Thoracic Aortogram)

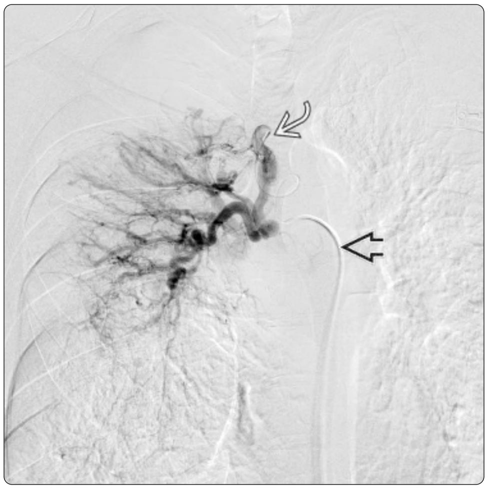


Bronchial Artery Embolization Procedure (Selective Right Bronchial Artery DSA)

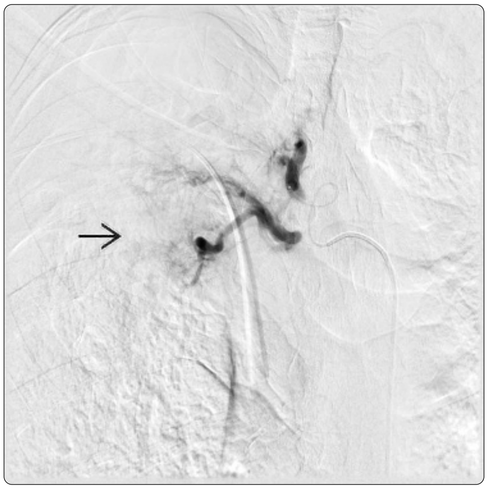


(Left) *Descending thoracic aortogram using a pigtail catheter shows a hypertrophied right intercostal bronchial trunk (RICBT) ➡.* *The aortogram will be a reference for selective catheterization of the bronchial artery.* **(Right)** *The pigtail catheter has been exchanged for a selective 5-Fr catheter ➡ to selectively catheterize the RICBT ➡. In addition to hypertrophy, the distal bronchial artery branches exhibit hyperemia ⇨. The intercostal branches follow the ribs ⇨.*

Bronchial Artery Embolization Procedure (DSA via Coaxial Microcatheter)

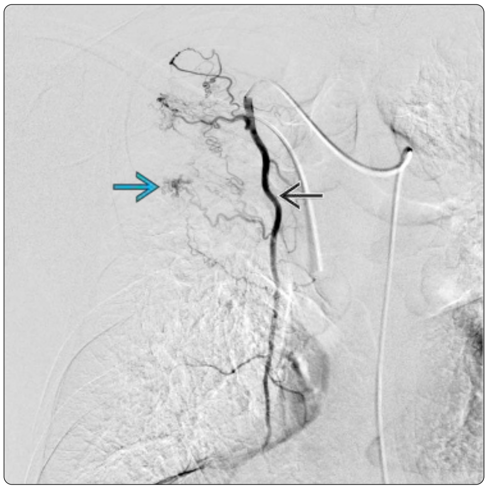


Bronchial Artery Embolization Procedure (Postembolization Bronchial DSA)

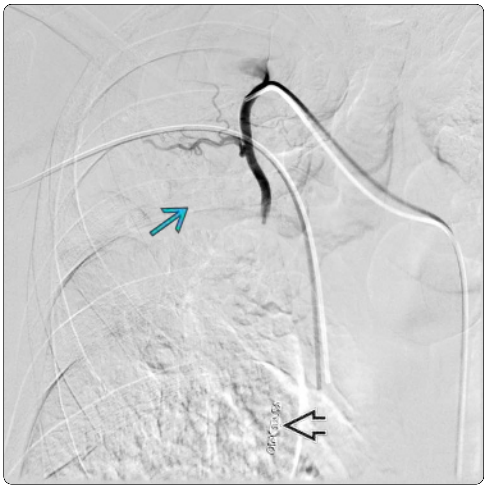


(Left) *Magnified DSA shows that a microcatheter ➡ has been introduced coaxially through the 5-Fr catheter ⇨ and positioned more distally in the bronchial artery in preparation for delivery of the embolic agent.* **(Right)** *DSA after embolization through the microcatheter using 300-500 μm spherical embolic particles shows reduced filling of distal branches, reduced parenchymal blush, and near contrast stasis ⇨. When these findings are present, this should be the endpoint of embolization.*

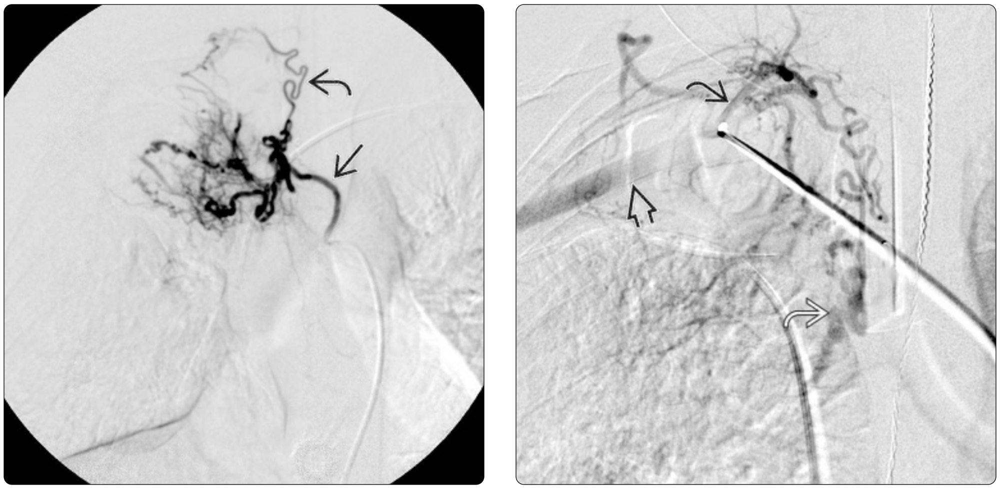
Internal Thoracic Artery Recruitment (Diagnostic)



Internal Thoracic Artery Recruitment (Postembolization)



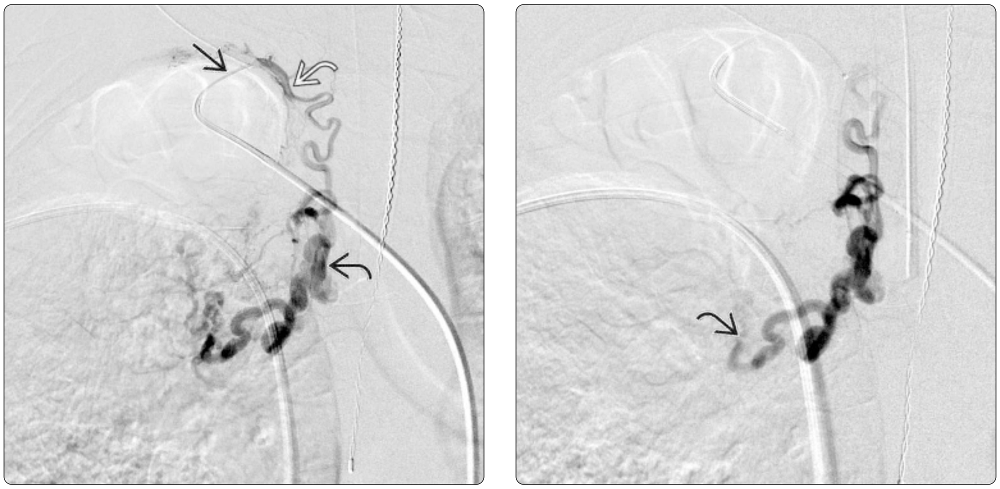
(Left) *Selective catheterization of the right internal thoracic artery (ITA) ⇨ shows multiple areas of lung hypervascularity indicating recruitment ⇨. This often occurs in diffuse chronic inflammatory processes that involve the pleural surface.* **(Right)** *Postembolization of the right ITA shows "near-stasis" with reduced right lung parenchymal abnormality ⇨. Embolization coils ⇨ placed within the caudal aspect of the ITA prevented embolic particles from traveling distally down the ITA during delivery.*



Systemic Collateral Recruitment (Selective Right Bronchial Artery DSA)

Systemic Collateral Recruitment (Selective Costocervical Trunk DSA)

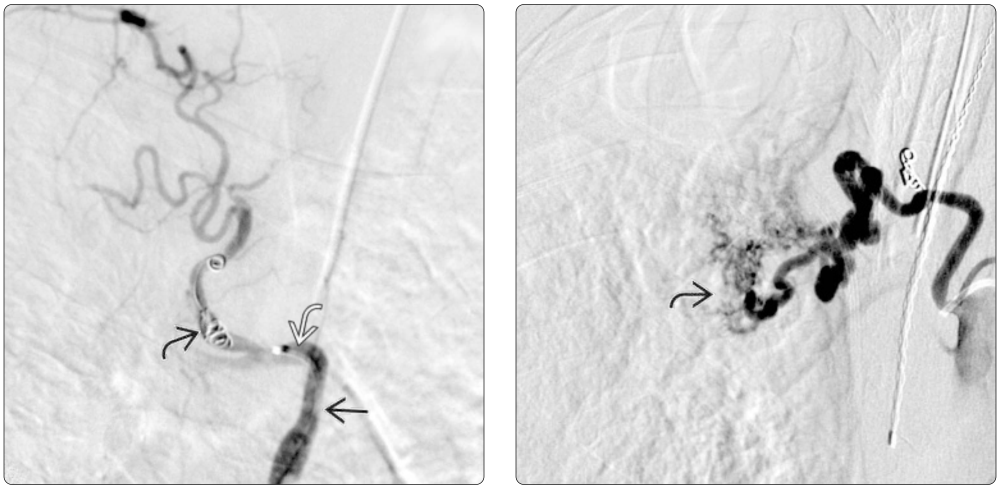
(Left) *Right bronchial artery → angiogram shows the hypertrophy and hypervascularity typically seen with hemoptysis. Additionally, there is a small, tortuous collateral vessel ↪ that courses cephalad toward the right lung apex.* **(Right)** *Selective DSA of the costocervical trunk ↪, which arises in normal fashion from the partially opacified right subclavian artery ⇨, shows that this is the source of the collateral vessel noted on the bronchial arteriogram. A portion of the right bronchial artery ➦ is opacified.*



Systemic Collateral Recruitment (DSA via Coaxial Microcatheter)

Systemic Collateral Recruitment (DSA After Collateral Embolization)

(Left) *DSA shows a microcatheter → subselectively positioned in the systemic collateral artery ➦ that communicates with the bronchial artery ↪. There is now more distal bronchial artery opacification. Systemic collateral recruitment can be a major source of recurrent hemoptysis. Such recruitment occurs when disease involves the pleura &/or chest wall.* **(Right)** *Particle embolization of the collateral supply to the bronchial artery territory has caused stasis ↪ distally in the bronchial artery.*

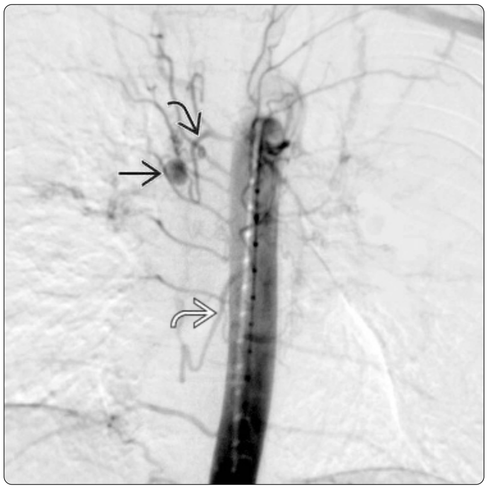


Systemic Collateral Recruitment (Systemic Connection Coil Embolization)

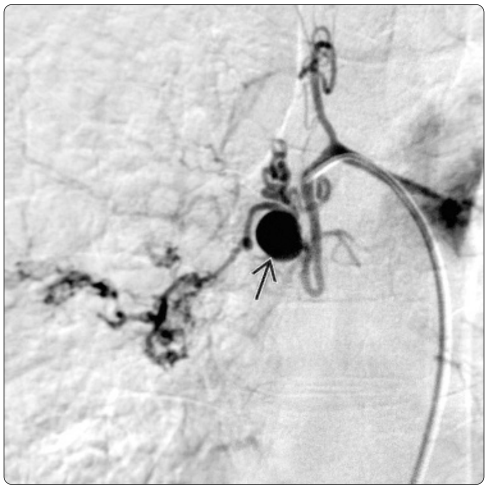
Systemic Collateral Recruitment (DSA After Particle Embolization)

(Left) *Magnification DSA shows a microcatheter ➦ in a branch of the right bronchial artery →. Embolization coils ↪ have been placed in the largest vessel communicating between the bronchial artery and the systemic collaterals.* **(Right)** *Repeat bronchial DSA was obtained after the particle embolization via the systemic collaterals and the coil embolization of the systemic-to-bronchial arterial communication. There is no filling of the collaterals, and there is "near-stasis" ↪ in the bronchial artery. The hemoptysis resolved.*

Bronchial Artery Pseudoaneurysm (Thoracic Aortic DSA Arteriogram)

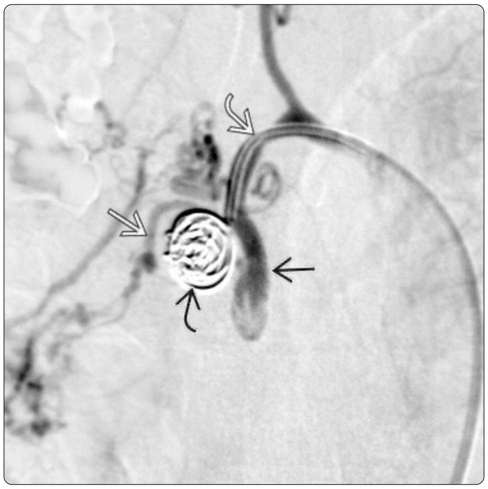


Bronchial Artery Pseudoaneurysm (Selective Right Bronchial Artery DSA)

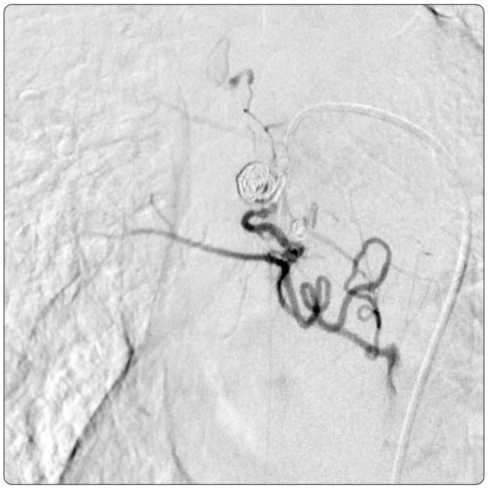


(Left) *Aortogram shows a pseudoaneurysm → arising from a hypertrophied right bronchial artery ↪. Another large bronchial artery ➦ supplies the lower right lung zone. An initial thoracic aortogram is useful in the angiographic evaluation of hemoptysis as it identifies the number of bronchial arteries, their origins, and course.* **(Right)** *Selective right bronchial arteriogram shows the pseudoaneurysm → and the arterial branching pattern. This serves as a guide for the subsequent embolization.*

Bronchial Artery Pseudoaneurysm (Coil Embolization via Microcatheter)

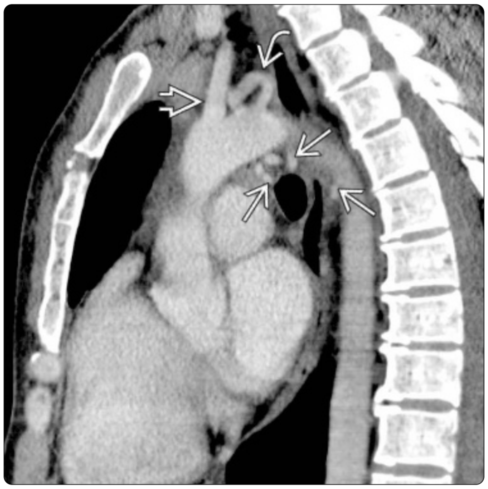


Bronchial Artery Pseudoaneurysm (Postembolization Bronchial DSA)

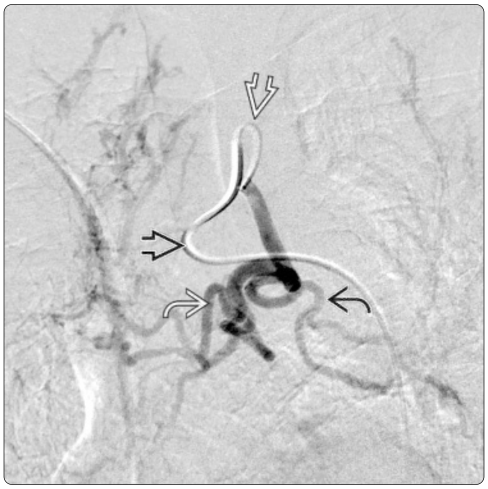


(Left) *Via the selective catheter ➦, a microcatheter was placed in the pseudoaneurysm and coils ↪ were introduced while preserving the arterial tree proximally → and distally ➔. Coils are not typically used for BAE in the absence of aneurysms, as they preclude repeat embolization if hemoptysis recurs.* **(Right)** *The same patient had recurrent hemoptysis 2 years later. Repeat bronchial angiography shows occluded aneurysms and a patent bronchial artery. The hemoptysis was controlled with particulate embolization.*

Aberrant Bronchial Artery Origin (Preprocedure CECT Evaluation)



Aberrant Bronchial Artery Origin (Selective Bronchial Artery DSA)



(Left) *CT shows an enlarged bronchial artery ➦ arising from the thoracic aortic arch, distal to the innominate artery ➩ and coursing inferiorly ➔ to supply the airways. Bronchial arteries have an aberrant origin in 30-40% of individuals. CTA is useful for depicting variant anatomy.* **(Right)** *DSA shows a Simmons catheter ⇨ in the vertical bronchial artery trunk, with a microcatheter ➩ directed inferiorly, positioned for particle embolization. The hypertrophied artery divides into right ➦ and left ↪ branches.*

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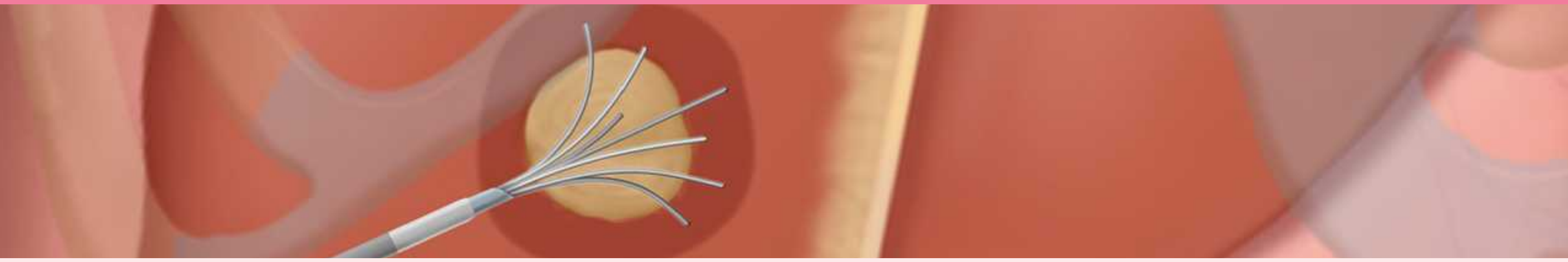
SECTION 4

Oncologic Procedures



Percutaneous Tumor Ablation **572**
Hepatic Chemoembolization **588**
Hepatic Radioembolization **600**
Renal Ablation and Embolization **612**
Thoracic Ablation and Embolization **622**
Musculoskeletal Ablation and Embolization **630**

Percutaneous Tumor Ablation

KEY FACTS

TERMINOLOGY

- **Ablation**: Direct application of chemical or thermal therapies to specific focal tumor (or tumors) in attempt to achieve eradication or substantial tumor destruction
- **Heat sink effect**: Flow of blood in nearby vessels cools tissue, limiting effectiveness

PREPROCEDURE

- **Indications**
    - Curative vs. palliation vs. debulking: Know goal
- **Lung tumor selection**
    - If > 1 tumor, select most rapidly enlarging, largest, or symptomatic 1st
    - Treat only 1 lung per setting
- Usually treat no more than 3 tumors in setting
- **Liver tumor selection**: Identify at-risk structures (lung, diaphragm, gallbladder, bowel, etc.) and plan mitigating interventions
    - Ablation can be easier on liver with marginal LFTs than TACE/TARE
- **Renal tumor selection**
    - Volume of normal parenchyma lost usually not significant enough to affect overall renal function
    - Size: Tumors < 4 cm (stage 1A) have significantly higher rate of complete response than larger tumors

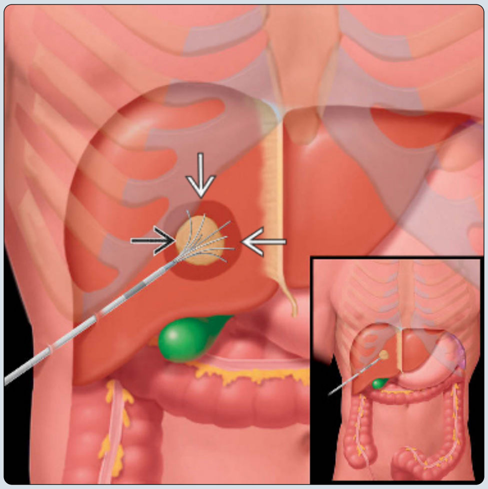
POST PROCEDURE

- Tumor ablation size poor marker of treatment success
- Lack of enhancement correlates with tumor necrosis on follow-up imaging
- Progressive decrease in size of mass over successive images good indication of successful treatment

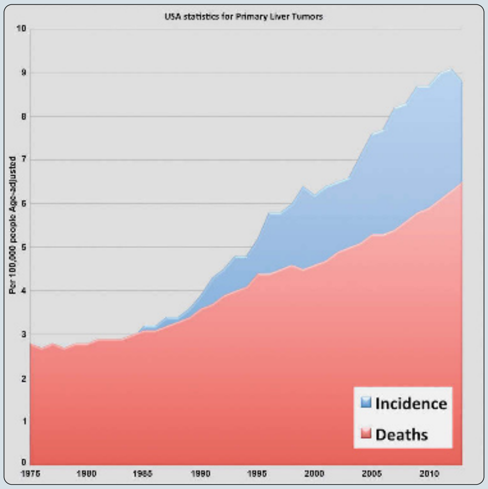
OUTCOMES

- Can achieve complete ablation in > 90% of hepatic and renal lesions ≤ 3 cm in size
- Lung tumors < 2 cm have complete ablation/cure rate of 78% of cases

Graphic of Percutaneous Thermal Ablation

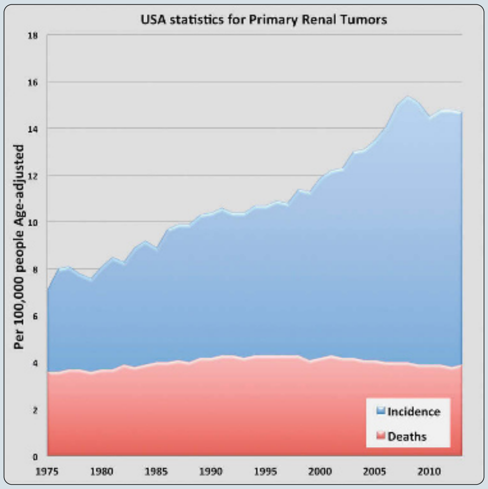


Epidemiology of Primary Liver Cancer (Hepatocellular Carcinoma)

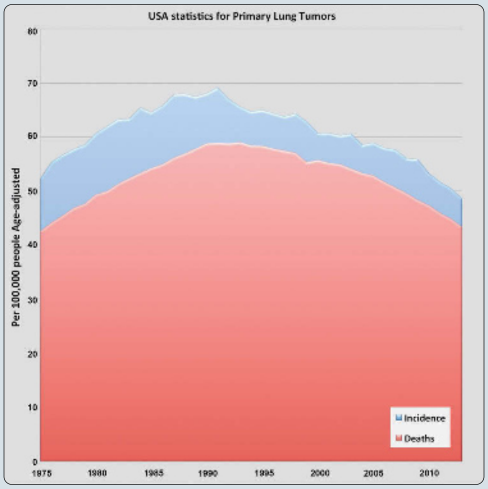


(Left) *The objective of an ablation with curative intent is to ablate the target lesion ⇨ plus a safety margin ➡. For lung and liver, the recommended margin is 10 mm, whereas for kidney cancer it is 5 mm.* **(Right)** *Incidence (blue) and mortality (red) of primary liver cancer (per 100,000 people) in the United States is shown. While the incidence and mortality were essentially equal in 1975, the incidence has been on the rise, while mortality has shown a relative decrease.*

Epidemiology of Primary Renal Cancer



Epidemiology of Primary Lung Cancer



(Left) *Incidence (blue) and mortality (red) of primary kidney cancer (per 100,000 people) in the United States is shown. While mortality has essentially remained the same or decreased, the incidence has significantly increased over time. This is attributable to earlier diagnosis and early implementation of potentially curative treatments.* **(Right)** *Incidence (blue) and mortality (red) of primary lung cancer (per 100,000 people) in the United States is shown, both of which plateaued in the early 1990s and have steadily decreased since then.*

TERMINOLOGY

Definitions

- **Ablation**: Targeted destruction of mass, most commonly by application of hyper- or hypothermia
    - Thermal ablation (heat) vs. cryoablation (cold)
- **Overall survival (OS)**: Length of time from either date of diagnosis or start of treatment for disease, such as cancer, to date of death of any cause
    - Usually expressed in median ± standard deviation
- **Cancer-specific survival (CSS)**: Length of time from either date of diagnosis or start of treatment for disease, such as cancer, to date of death from disease
    - Patients who die from causes unrelated to disease are not counted in this measurement
- **Progression-free survival**: Length of time (from set point, usually treatment) that patient demonstrates no disease progression
- **Time to progression**: Length of time (from set point, usually treatment) until patient shows disease progression
    - Mortalities are excluded
- **Disease-free survival (DFS)**: Length of time after treatment, until patient dies or shows evidence for recurrent disease
- **Tumor epidemiology**
    - **Lung cancer**
        - Most common newly diagnosed primary solid malignancy worldwide
        - Incidence: 60.4 new tumors/100,000 people in North America
        - Mortality: 45.0 attributable deaths/100,000 people per year
        - Most commonly discovered in 7th decade of life
        - Lung is most common site of secondary neoplastic involvement
    - **Liver cancer**
        - Hepatocellular carcinoma (HCC)
            - Most common primary liver malignancy
            - 6th most common newly diagnosed primary malignancy worldwide
            - Incidence: 8.4 new primary tumors/100,000 people in North America
            - Mortality: 6.3 attributable deaths/100,000 people per year
        - Colorectal cancer (CRC) metastasis
            - Liver is most common location
            - Colon cancer is 3rd most common newly diagnosed solid cancer worldwide
            - incidence: 38.9 new diagnoses/100,000 people in North America
            - Mortality: 14.7 attributable deaths/100,000 people per year
            - Resection/ablation of CRC mets improves CSS
    - **Kidney cancer**
        - Renal cell carcinoma (RCC)
            - Most commonly diagnosed renal malignancy
            - 12th most commonly newly diagnosed primary malignancy worldwide
            - Incidence: 15.9 new diagnoses/100,000 people in North America
            - Mortality: 5 attributable deaths/100,000 people per year
            - Long-term CSS for stage 1A disease is 95-98%

Ablation Modalities

- **Radiofrequency ablation (RFA)**
    - Physics
        - Relies on electrical conduction through tissue for heat generation
        - Closed circuit necessary for conduction; body acts as resistor
        - Direct radiofrequency heating
            - Occurs within millimeters of applicator needle
        - Thermal conduction
            - Heat transfer more distally, therefore good thermal conductivity crucial for large ablation
            - Quick charring (dehydration) of tissue increases resistance, opens circuit, and limits ablation zone
            - Slow, gradual "cooking" more effective than fast ablation
        - Common current frequency of 400-500 kHz
    - Disadvantages
        - Irregular ablation shape, depends on thermal conductivity of tissue
        - Charring limits effectiveness
        - Heat sink effect
            - Flow of blood in nearby vessels cools tissue, limiting effectiveness
        - Impedance (instead of temperature) regulating systems may lengthen total procedure time and increase ablation zone
        - Grounding pads required for monopolar systems
        - May require slow and lengthy treatment to effectively kill tumor
- **Microwave ablation (MWA)**
    - Physics
        - Relies on dielectric heating
            - Alternating electromagnetic (EM) field applied to imperfect dielectric material (tissue), forces water molecules in tissue to oscillate
            - Water molecules oscillate out of phase with EM field
            - Frictional energy loss generates heat
            - Higher water content = better heat absorption and conductivity = larger ablation zone
        - Frequencies usually of 30 MHz to 30 GHz
        - Relative permittivity: How well materials accept EM field (capacitance)
            - Lower the permittivity, the less the movement of energy from source dispersed through tissues
            - Low relative permittivity: Bone, spleen
            - High relative permittivity: Muscle, lung, liver
        - Effective conductivity: How well tissue absorbs microwave energy
            - Lower the conductivity, the higher the thermal energy deposited locally and the more effective the ablation around antennae; however, the more shallow the penetration for given frequency
            - Low conductivity: Bone, lung, liver
            - High conductivity: Muscle, blood, spleen
    - Advantages

  - Ablation volume is more predictable, as it does not depend on thermal conductivity of tissue
  - Can pass through and heat tissue at any temperature or water content
  - Less susceptible to heat sink by producing larger areas of active heating
  - Does not require grounding pads
- **Cryoablation**
  - Physics
    - Relies on Joules-Thomson effect
      - ☐ Compressed gas circulates within double-barreled probe
      - ☐ Gas released within probe results in sudden pressure drop
      - ☐ Resultant temperature drop cools surrounding tissues
    - Process consists of alternate freezing and thawing of tissue (commonly 10 min, 8 min, 10 min)
    - Multifaceted cellular death mode: Cell membrane fracture, apoptosis, vessel thrombosis/ischemia
    - Argon gas or nitrogen gas/liquid are required component
    - Each probe has characteristic isotherms (size and shape of surface with same temperature)
    - Temperatures drop to ~ -150°C at probe
    - Heat-pump effect: Nearby vessels may increase temperature and limit ablation margin
  - Advantages
    - Well tolerated (minimal pain)
    - High level data supporting its use over RFA/MV in renal tumor ablation (higher efficacy)
    - Prospective data suggest efficacy comparable to standard of care (partial nephrectomy)
    - "Ice ball" readily visible with CT (US/MR) guidance
      - ☐ Represents 0°C isotherm (not lethal)
      - ☐ Lethal isotherm (-20°C) ~ 2-3 mm inside visible "ice ball"
    - Operator can sculpt irregularly shaped ablation zone by altering orientation of multiple probes
  - Disadvantages
    - More expensive, as multiple probes may be required
    - System requires gas availability and storage

PREPROCEDURE

Indications

- **General**
  - Goals of ablation
    - **Cure**: Complete ablation in potentially curative cases
      - ☐ Stage IA kidney cancer
      - ☐ HCC ≤ 3 cm
      - ☐ Lung cancer ≤ 3 cm
    - **Palliation**: Treatment of index tumor to achieve symptomatic relief or prevent impending symptoms
    - **Debulking**: Tumor cytoreduction or control of disease progression
      - ☐ Occasionally to improve efficacy of systemic chemotherapy
- **Lung**
  - Non-small cell lung cancer
    - Tumors < 3 cm: Goal of complete ablation/cure
    - Gold standard remains surgery
      - ☐ Larger resection margin
      - ☐ Nodal resection
      - ☐ Tissue diagnosis
    - Stereotactic body radiotherapy (SBRT) as good as or superior to RFA/MW in outcomes, disease progression, and survival for larger tumors
    - Ablation as good as SBRT for smaller tumors (< 2 cm)
    - At least 1-cm ablation margin required (spiculated spread)
  - Metastases
    - Similar survival benefit with both surgical resection and percutaneous ablation
      - ☐ Already metastatic disease; therefore nodal resection and tissue diagnosis no longer advantages
    - Ablation can be repeated
    - At least 5-mm ablation margin required (rounded lesions)
- **Liver**
  - HCC
    - Potentially curative for < 3-cm lesions
      - ☐ Same OS compared to surgical resection
    - Downstage tumor to within Milan criteria
    - Maintain patient to within transplant criteria
  - Unresectable hepatic metastases
    - Patients with low burden colorectal metastases may benefit from ablation
      - ☐ OS similar to that of resection
    - Other oligometastatic liver disease may be ablated but high-level evidence lacking
- **Kidney**
  - RCC
  - For tumors < 4 cm (stage 1A), goal is cure
  - For tumors > 4 cm but < 10 cm, organ confined without nodal or distant metastasis
    - Increased technical complexity
    - Often requires more probes &/or staging (2 procedures)
    - Higher potential for incomplete treatment
      - ☐ Given slow rate of growth, can be retreated safely
  - Data suggests cryoablation has higher efficacy than RFA/MW
  - Cryoablation comparable to surgery in overall and CSS for stage IA
    - Lower morbidity than surgery

Contraindications

- **Lung**
  - Life expectancy < 6 months (from comorbidities)
  - Severe underlying pulmonary disease: Poor PFTs
  - Prior pulmonary surgery/borderline respiratory reserve
  - Uncorrectable coagulopathy
  - Active infection
  - No percutaneous window
  - Abutting or contiguous with mediastinum or hilum/large vessel
- **Liver**
  - Life expectancy < 6 months
  - Child-Pugh class C cirrhosis

  - Functional status > Eastern Cooperative Oncology Group (ECOG) 2
  - Active infection
  - Decompensated liver disease
  - Bile duct or major vessel invasion
  - Significant extrahepatic disease
  - Uncorrectable coagulopathy
  - No percutaneous window
- **Kidney**
  - Life expectancy < 1 year (especially for small tumors)
  - Uncorrectable coagulopathy
  - Large tumor near pelvis: Risk of collecting system/major vessel damage
    - Can protect ureter/collection system by placement of ureteral stent or by pyeloperfusion
  - RCC with invasion of renal vein or regional lymph node involvement
    - Advanced stage: Ablation is **never** curative
    - Surgery can be curative
  - Active infection
  - No percutaneous window

Getting Started

- Things to check
  - **General clinical history and physical examination**
    - Assess Indications and goal
    - Review patient medications
      - Hold anticoagulation/antiplatelet medication as appropriate
    - Pacemaker/defibrillator
      - Consult with electrophysiologist before RFA/MW procedure to ensure safety
      - May also require postablation interrogation
      - Not necessary for cryoablation
  - **Consent**
    - Discuss risks, benefits, possible side effects in detail with patient/family
    - Postablation syndrome
      - Inflammatory response caused by tumor necrosis
      - Associated with fever, malaise, anorexia
    - Incomplete tumor ablation
  - **Lung-specific consent**
    - Mild to moderate pain, especially if near pleura (usually controlled with PO analgesics)
    - Mild, self-limiting fevers
    - Pneumothorax: Risk of 20-30%
      - May require chest tube placement
    - Hemorrhage, hemoptysis
    - Bronchopleural fistula
      - Possibly requiring chest tube or surgical intervention
    - Infection/abscess formation
    - Air embolism
  - **Liver-specific consent**
    - Bleeding
    - Damage to bowel, gall bladder, diaphragm
    - Infection/abscess
      - Highest in setting of bilioenteric anastomosis (60-80%)
    - Bile duct damage (0.1-1.0%), usually of little clinical significance
    - Tract seeding (extremely rare)
      - Mitigated with tract coagulation upon exit
  - **Kidney-specific consent**
    - Hemorrhage requiring intervention (3-4%)
    - Ureteral injury
    - Damage to nontarget structures (intestine, adrenal gland, genitofemoral or intercostal nerves)
    - Damage to genitofemoral or intercostal nerve may cause pain or sensory/paresthesias or muscle laxity
      - Usually resolves in days to weeks
  - **Lung tumor/patient selection**
    - In general, if patient can undergo CT-guided biopsy, can undergo ablation
    - Pulmonary function: Referred patients usually not surgical candidates
      - No lower limits on FEV_1 or DLCO
      - Is patient able to lie supine/prone for procedure
      - General anesthesia not needed in general; however, difficult airway patients, cases where complications are anticipated, severe lung disease patients, etc., may require anesthesia
    - Tumor selection
      - If > 1 tumor, select most rapidly enlarging, largest, or symptomatic 1st
      - Treat only 1 lung per setting
      - Usually treat no more than 3 tumors in setting
      - Size: < 3 cm for best outcomes
      - Location: Peripheral at lower risk of vascular complications/bleeding
      - Ablation provides similar OS benefit to sublobar resection and radiotherapy
      - Sublobar resection, however, provides higher local tumor control rate than ablation or radiotherapy
  - **Liver tumor/patient selection**
    - ECOG status < 3
    - Liver function tests (LFTs)
      - In general, total bilirubin should be < 4
      - Bilirubin, AST, and ALT TREND as important as absolute value
      - Values should be taken in context of patient's ECOG status
      - Tumor marker: Pre and post values help assess response to treatment
    - Tumor selection for ablation
      - Primary treatment modality over partial hepatectomy for solitary tumors < 3 cm
      - Location: Identify at risk structures and plan mitigating interventions (lung, diaphragm, gallbladder, bowel, etc.)
    - Alternatives: Transarterial chemoembolization (TACE) or radioembolization (TARE)
      - TACE/TARE can be harder on liver with marginal LFTs than ablation
      - Option for larger or more numerous tumors
  - **Kidney tumor patient selection**
    - Renal function tests
      - Volume of normal parenchyma lost is usually not significant enough to affect overall renal function

      - ☐ Ablation is actually ideal for patients with solitary kidney, prior surgery, or those post transplant
    - Tumor selection for ablation
      - ☐ Size: Tumors < 4 cm (stage 1A) have significantly higher rate of complete response than larger tumors
      - ☐ Multiple treatments may be required for larger tumors
      - ☐ Location: Noncentral location has higher complete response rate
      - ☐ For goal of cure, tumor should be confined to kidney, within Gerota fascia, and without vascular invasion
- Medications
  - Anesthesia
    - 1% lidocaine local anesthetic
    - Moderate sedation via IV
      - ☐ Fentanyl, midazolam, meperidine typically used
      - ☐ Consider timing and depth of dosing before procedure if patient will need to follow breathing commands
    - Anesthesiology assistance if propofol/general anesthetic warranted
    - If procedure can be done safely via moderate sedation, this will benefit patient most with regards to sedation risk and recovery post procedure
  - Premedication
    - **Liver**: Octreotide pretreatment recommended for ablation of neuroendocrine metastasis
    - **Kidney**: α- and β-blocker premedication recommended for ablation near adrenal glands
  - Prophylactic antibiotics
    - **Lung**: No data indicating benefit
    - **Liver**: If prior biliary instrumentation/surgery
      - ☐ Increases risk of postprocedural infection/hepatic abscess
      - ☐ Pre-/postprocedure antibiotics warranted
    - **Kidney**: No data indicating benefit

PROCEDURE

Baseline Imaging and Planning

- Baseline imaging to confirm positioning, target, access location and angle, number of probes, and need for hydro-air dissection
  - Evaluate for changes since original diagnostic scan
  - Change planned approach, access, number of probes as warranted based on these findings
    - Is tumor now abutting structure in need of protection
  - Evaluate planned route of access for obstacles
    - Are bowel/pleura/organs obscuring needle approach
      - ☐ If so, reposition patient and repeat planning scan

Probe Insertion/Positioning

- Mark expected site of access on skin
- Prepare and drape patient using standard sterile technique
- Prepare procedure table, and assure that ablation equipment available and working appropriately
  - For cryoablation, test probe in bowl of saline
    - Ensure no gas leak
    - Ensure "ice ball" forms and thaws
- Anesthetize skin at site of entry with local anesthetic
- Make dermatotomy with #11 scalpel
- Utilizing laser-guidance system of CT fluoro
  - Insert probe(s) few cm and rescan
  - Adjust angle and depth of probe(s)
  - Repeat steps, gradually advancing probe(s)
  - Place probe(s) so that expected ablation zone covers target **plus** ablation margin
    - Ablation margin 1 cm for lung and liver
    - Ablation margin 0.5 cm for kidney
  - If > 1 probe, keep them parallel and within 2 cm of each other

Added Maneuvers

- Dissection
  - Hydrodissection
    - Place 21-g needle between target and nontarget organ
    - Inject saline (cryoablation) or sterile water (RFA/MWA)
    - Monitor intermittently to ensure adequacy of dissection
  - Air dissection
    - Place spinal needle between target and nontarget organ
    - Air used to protect structures in nondependent location
  - Iatrogenic pneumothorax
    - Used to protect chest wall **after** ablation probes placed
  - Cryoprobes "stick" to target lesion during freezing
    - Used to pull/push/torque kidney away from nontarget organ

Intraprocedural Monitoring of Patient and Treatment

- Monitor vitals and depth of sedation
  - Sedation should be titrated as indicated
    - Analgesia requirement usually lower for cryoablation
- Treatment
  - RFA
    - Cycle duration varies and depends on system used and tissue type; typically 6-12 min
    - May require 2 or more cycles to cover tumor and surrounding margin
    - Ablation endpoint is vendor dependent and based on temperature, impedance, etc.
  - MWA
    - Time of cycle based on tumor volume and desired size of ablation; typically 6-12 min
      - ☐ Larger volume usually means increased power and duration of treatment
  - Cryoablation
    - Typical cycle consists of 10-min freeze followed by 8-min active thaw
    - 2 cycles always performed
  - Serially monitor treatment with imaging while in progress regardless of modality
    - Assess for appropriate coverage
    - Determine effectiveness of maneuvers to mitigate nontarget damage

Completion Imaging

- Once ablation complete, remove probes, clean area, place bandage
    - For cryoablation, probe cannot be removed (or placed) until it reaches > 10°C
    - For lung ablation, standard occlusive petroleum dressing recommended
- Obtain postprocedure scan
    - Confirm effective ablation
        - e.g., assess cryoablation for "ice ball" visibility
    - Ensure no complications (usually hemorrhage or pneumothorax)

Recovery

- Monitor patient for at least 2 hr for development of pain, signs of bleeding, or pneumothorax
- For lung ablations, post procedure radiograph warranted
    - If no pneumothorax during procedure
        - Obtain single chest radiograph 1-3 hr post procedure and, if negative, may discharge patient
    - If pneumothorax during procedure
        - If large, expanding, or symptomatic, place chest tube
        - If small, stable, and asymptomatic, may discharge patient
- For liver and renal ablations, no postprocedure imaging warranted
    - If signs of bleeding develop, consider NECT

Things to Avoid

- Thermal injury to
    - **Lung**
        - Intercostal nerves
            - ☐ To move ablation target away from these structures, use hydrodissection/iatrogenic pneumothorax (after having placed ablation probe)
        - Air embolism
            - ☐ Although extremely rare, is difficult complication to avoid, but attention to pulmonary vein size and location in relation to tumor ablation access points and whether or not to treat particular tumors may be helpful
    - **Liver**
        - Biliary tree, major blood vessels
            - ☐ Heat sink effect protects blood vessels from thermal injury
            - ☐ Bile duct injury uncommon (0.1-1.0%), usually of little significance
            - ☐ Caution in ablating hilar tumors may help limit risk of damage to larger ducts, which may have more clinical significance
        - Gallbladder/adjacent bowel, kidney, adrenal, diaphragm, nerves
            - ☐ Peripheral/subcapsular ablations can be performed safely after hydrodissection with adjustments made as necessary throughout case
            - ☐ Change in positioning prior to ablation may allow gravity to move at-risk nontarget structures away from ablation zone
    - **Kidney**
        - Ureter
            - ☐ If this will possibly be within field of ablation, should be protected with internal stent placement prior to ablation
        - Peritoneum, iliofemoral nerve, psoas muscle
            - ☐ Positioning patient &/or hydrodissection help to avoid nontarget ablation of these structures as well

Alternative Procedures/Therapies

- Radiologic
    - Liver
        - If no safe way to reach/treat solitary lesion in liver percutaneously, other options to consider would include transarterial liver-directed therapies
        - Chemoembolization
        - Radioembolization (Y-90 embolization or selective intraarterial radiotherapy)
- Surgical
    - **Lung**
        - Surgical resection
            - ☐ Pneumonectomy vs. wedge resection
            - ☐ Patients referred for lung ablation often not surgical candidates
        - External beam radiotherapy
    - **Liver**
        - Hepatic transplant
        - Surgical resection
            - ☐ Patient referred for liver tumor ablation often deemed unsuitable for surgery before ablation has been performed
        - External beam radiotherapy
            - ☐ SBRT
        - Open/laparoscopic assisted ablation
    - **Kidney**
        - Surgical resection
        - Open/laparoscopic assisted ablation

POST PROCEDURE

Things to Do

- Schedule serial follow-up imaging
- Schedule follow-up clinic appointment
    - In event of postprocedural pain/complications
    - Routine follow-up/discuss subsequent imaging

Follow-Up

- Tumor ablation size is poor marker of treatment success
    - However, ablation zone needs to be larger than tumor to achieve adequate margin
- Lack of enhancement correlates with tumor necrosis on follow-up imaging
- Use same pre- and posttreatment imaging modality
    - Provides for most accurate comparison of response
- **Lung**
    - 1st follow-up at least 3 months post ablation
        - Especially true if PET/CT, as inflammation may result in false-positive reading
    - Repeat ablation if necessary
    - Target must gradually shrink over successive CT scans

  - Variety of blood tumor markers can be obtained at clinical follow-up depending on tumor origin and compared to preprocedural values to corroborate treatment effectiveness
    - For instance, CRC = CEA; ovarian cancer mets = CA-125; breast cancer = CA 15-3/CA 27.29, etc.
- **Liver**
  - 1-2 month, CEMR modality of choice
    - CECT acceptable if patient cannot have MR
  - Blood tumor markers also helpful in corroborating treatment effectiveness in both primary and metastatic tumors of liver
    - Examples aside from those listed for lung include HCC = AFP; neuroendocrine mets = chromogranin A; pancreatic cancer = CA 19-9, etc.
  - Also important in liver treatment follow-up: Serological measurement of liver function, including total bilirubin, AST, ALT, alkaline phosphatase
    - If patients return with symptoms (i.e., pain, fatigue, fevers) in postprocedure setting, these values will help determine etiology of problem
- **Kidney**
  - 3, 6, 9 month, and then annual follow-up recommended
  - Due to slow growth rate, residual disease may not be apparent until later
  - Patients with history of RCC at higher risk for new RCC, thus long-term annual follow up should be considered

OUTCOMES

Complications

- Most feared complication(s)
  - Life-threatening hemorrhage
    - Access to interventional angiographic facilities &/or surgical assistance required, should patient become hemodynamically unstable
- Immediate/periprocedural complication(s)
  - Pain: Typically well controlled prior to discharge
  - **Lung**
    - Hemorrhage: Hemoptysis, usually self-limiting, considered common
    - Pneumothorax: Self-limiting, no treatment unless symptomatic
  - **Liver and kidney**
    - Hemorrhage: Postprocedure CT to evaluate
- Delayed complication(s)
  - **Lung**
    - Pneumonia, abscess, tumor tract seeding (exceedingly rare)
  - **Liver**
    - Biliary stricture, abscess, tumor tract seeding (exceedingly rare)
  - **Kidney**
    - Ureteral stricture, cutaneous nerve injury (paresthesias)
- Other complications
  - Postablation syndrome
    - Systemic inflammatory response occurring 2-10 days after ablation procedure
    - Self-limiting fever, myalgia, fatigue
      - ☐ Treat fever with antipyretics

Expected Outcomes

- **Lung**
  - Tumors < 2 cm = complete ablation/response rate > 80%
  - Metastasis: Outcomes very similar between surgical metastectomy and percutaneous ablative procedures for lesions < 3 cm
- **Liver**
  - Early-stage HCC (solitary < 3 cm and Child class A)
    - 3- and 5-year survival of 89% and 61%, respectively
  - Multiplicity of tumors and worse Child class leads to poorer outcomes
  - Metastasis (overall)
    - DFS at 3 and 5 years of 30.4% and 23.9%, respectively
    - DFS for surgery at 3 and 5 years better at 45.2% and 39.7%, respectively
- **Kidney**
  - Tumors < 4 cm (stage 1A), DFS rate at 5 years of 97%
    - Similar to that of standard of care, radical nephrectomy
  - Tumors 4-10 cm, organ confined without nodal or distant metastasis or vascular invasion (stage 1B)
    - 84-97% 5-year DFS
    - Given slow growth rate, repeat treatments often very successful, if warranted

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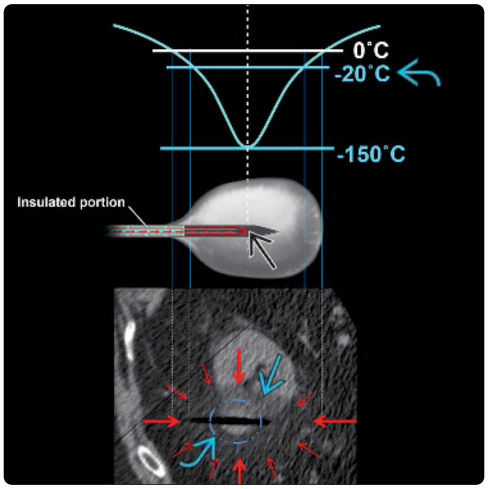
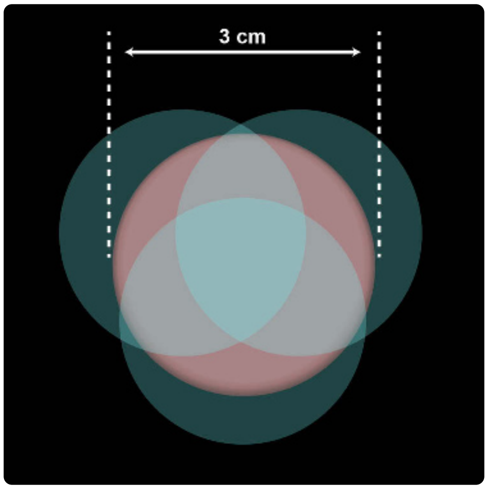
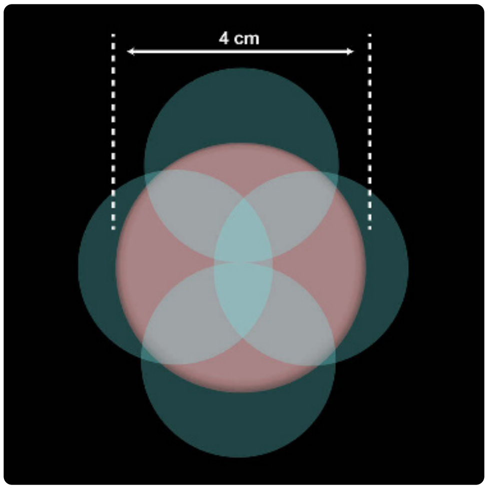


Physics of Cryoablation

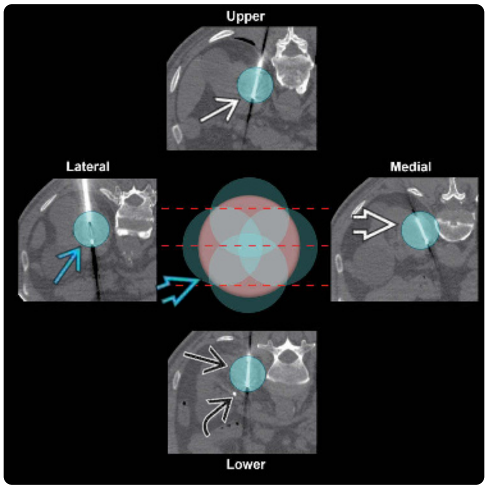


Overlapping Ablations (3 cm)

(Left) *Argon gas undergoes sudden decompression within the probe →, cooling surrounding tissue (Joules-Thomson effect). The "ice ball" (red arrows) shows the 0° isotherm →. A lethal -20° isotherm → lies ~ 2 mm within it.* **(Right)** *The ablation volume must be "sculpted" by arranging multiple probes or performing overlapping ablations so that the entire target volume is covered. A probe with a 3-cm effective ablation diameter requires 3 overlapping ablations to treat a 3-cm lesion.*

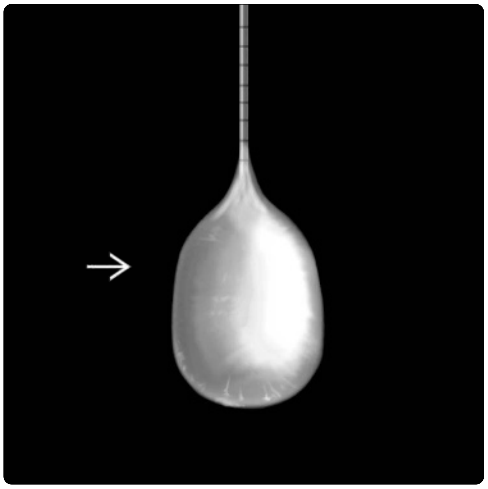


Overlapping Ablations (4 cm)

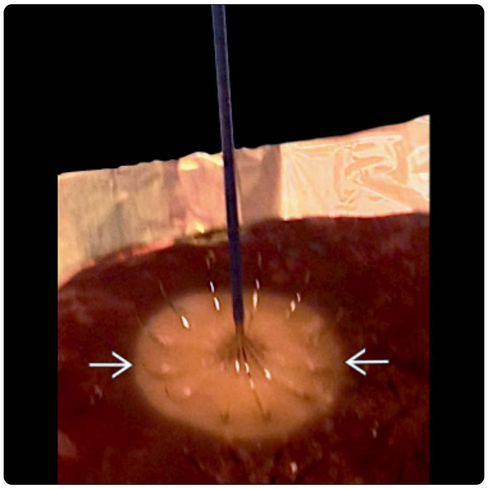


Overlapping Ablations (CT Volumetric Software)

(Left) *A probe with a 3-cm effective ablation diameter requires 4 overlapping ablations to treat a 4-cm lesion.* **(Right)** *CT shows 4 ablation probes placed at the superior →, lateral →, medial →, and inferior → edges of the tumor. Proper probe placement provides an overlapping geometry and adequate margin →. Nephroureteral stent placed to protect the collecting system → is noted incidentally.*



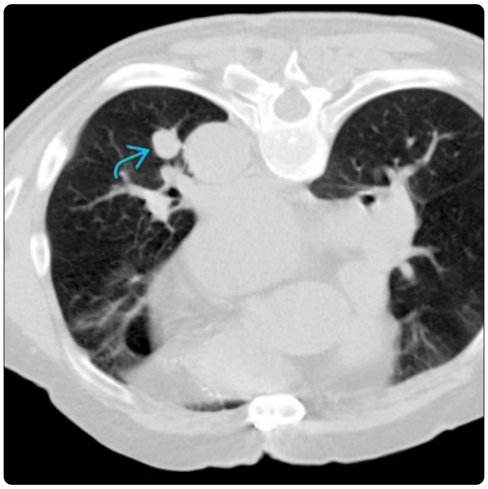
"Ice Ball"

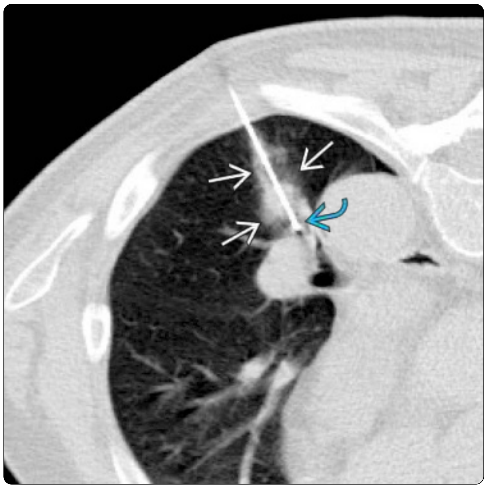


RFA

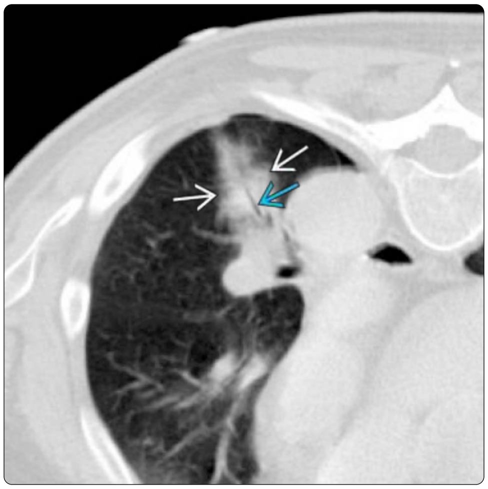
(Left) *An in vitro "ice ball" formation is shown. The oval-shaped "ice ball" → is visible on imaging modalities and represents the 0° isotherm. It is not lethal to tissue. The -20° lethal isotherm resides ~ 2 mm inside the visible "ice ball."* **(Right)** *In vivo radiofrequency ablation (RFA) with a multitined probe is shown. The ablation zone → extends only 2-3 mm beyond the tines; therefore, complete tumor encapsulation by radiofrequency tines is required for effective ablation.*

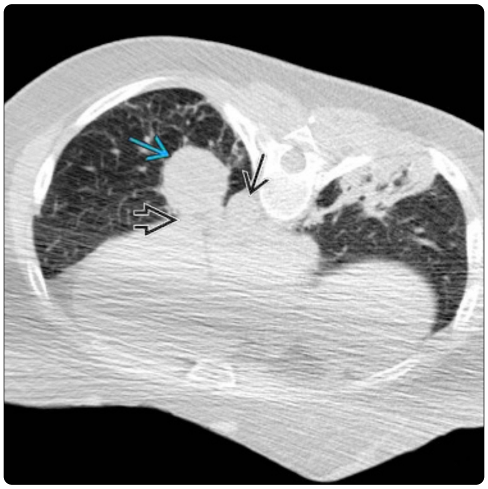
(Left) *64-year-old man with a single, 2-cm metastatic colon cancer lesion* ↪ *to the left lower lung is shown. Multidisciplinary review recommended percutaneous ablation, as evidence shows overall survival is similar between ablation and surgery for small (< 3-cm) lesions.* **(Right)** *Intraprocedural CT during microwave ablation (MWA) shows the probe* ↪ *penetrating the lesion with its tip just distal to it. A halo* ➔ *is seen surrounding the target, representing the ablated margin.*


Monometastatic Colon Cancer (CT Localization of Lesion)

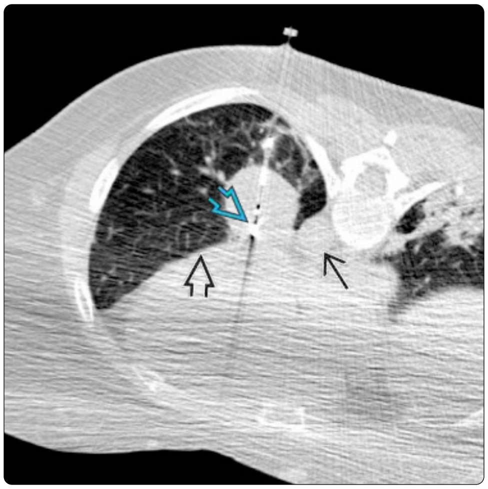

Monometastatic Colon Cancer (Probe Placement & Ablation)

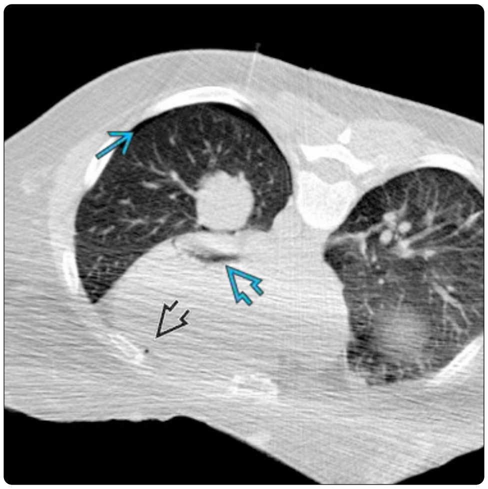
(Left) *Immediate postablation image shows the probe "ghost" track* → *through the target lesion. The ground-glass ablation margin* ➔ *is seen surrounding the lesion.* **(Right)** *Axial CT in a 62-year-old woman with a solitary left lung breast cancer metastasis* → *is shown. It abuts the pericardium* ⇨ *and the aorta* → *. Multidisciplinary review recommended percutaneous ablation.*


Monometastatic Colon Cancer (Post Ablation)


Coronary Artery Air Embolism During Ablation (CT Localization of Lesion)

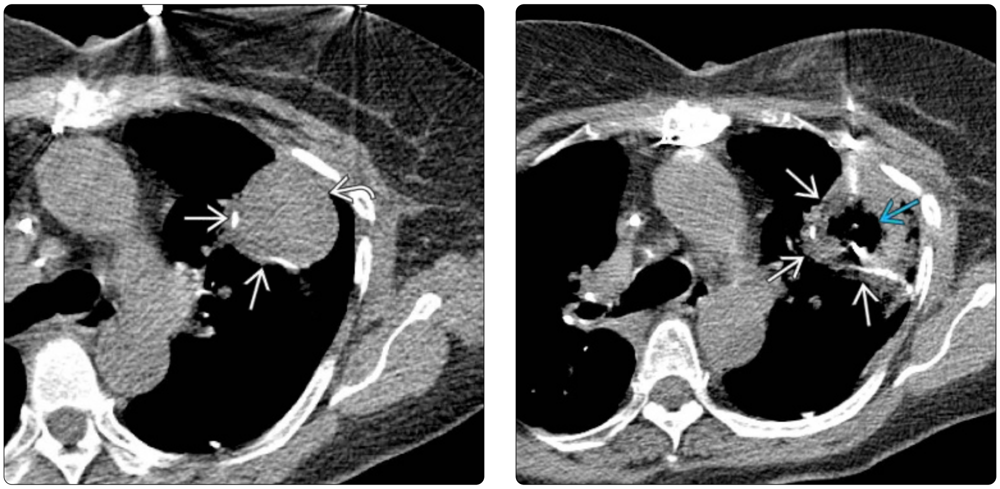
(Left) *The radiofrequency electrode tip* ⇨ *(same patient) is at the distal margin of the mass, directed away from the aorta* → *and not violating the pericardium* ⇨*.* **(Right)** *Intraprocedural CT in the same patient revealed pneumothorax* → *and air in the left ventricle* ⇨ *and left anterior descending coronary artery* ⇨*. ECG changes were noted that resolved after administration of epinephrine. The patient recovered fully. It was presumed that positive airway pressure forced air from a bronchus into a traversed pulmonary vein.*


Coronary Artery Air Embolism During Ablation (Probe Placement & Ablation)


Coronary Artery Air Embolism During Ablation (Intraprocedural CT)

Postresection Margin Uterine Cancer Recurrence (CT Localization of Lesion)

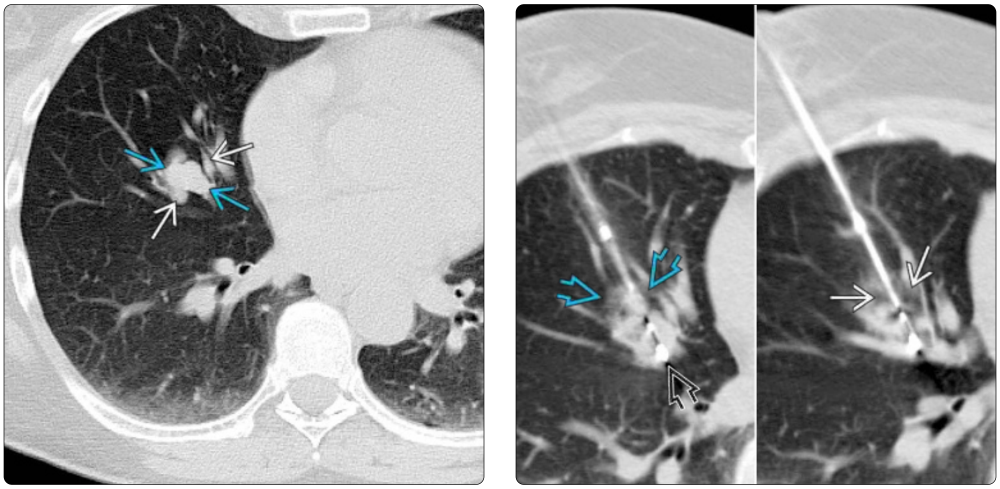
Postresection Margin Uterine Cancer Recurrence (Probe Placement & Ablation)



(Left) *An axial CT shows a 76-year-old woman with monometastatic uterine cancer post left upper lobe resection with local recurrence at resection margin ➡. The mass abuts the pleural surface ➡.* **(Right)** *Intraprocedural MWA shows gas formation within the target lesion ⇨. While this is a sign that high temperature was achieved, it does not guarantee effective ablation. Overlapping ablation are necessary to ensure adequate margin ablation ➡.*

Adenoid Cystic Carcinoma Metastasis (CT Localization of Lesion)

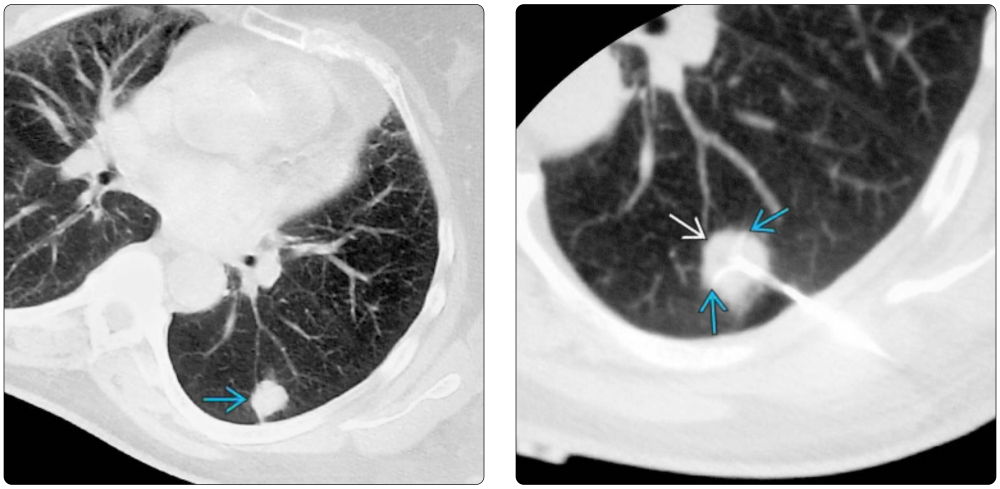
Adenoid Cystic Carcinoma Metastasis (Probe Placement & Ablation)



(Left) *A baseline axial CT of a 46-year-old woman with adenoid cystic carcinoma metastasis to the lung shows a 2-cm solid lesion ⇨ surrounded by pulmonary vessels ➡.* **(Right)** *Because of the proximity to the vessels, heat sink is a concern. A large microwave probe ⇨ is placed along the long axis of the lesion. During ablation, ground-glass opacity develops around the target ⇨. As MWA progresses, the tumor itself becomes more radiolucent centrally ➡.*

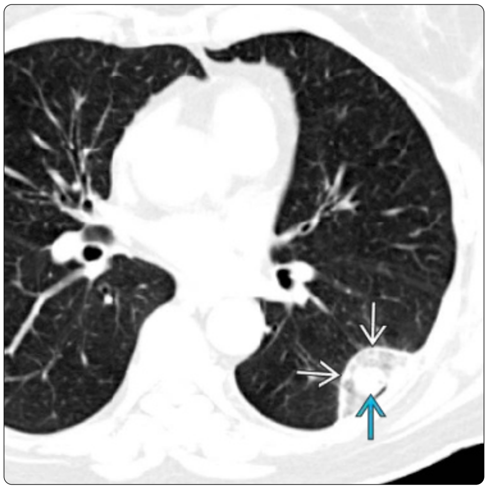
Metastatic Colon Cancer (CT Localization of Lesion)

Metastatic Colon Cancer (Probe Placement & Ablation)

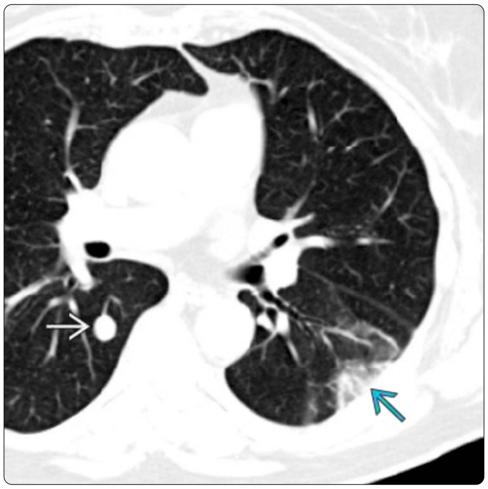


(Left) *An axial CT shows a 72-year-old man who was 3 years post colectomy for primary colon cancer. A 2-cm single new lesion is seen in the left lower lobe ⇨. An aggressive approach was decided and an ablation recommended.* **(Right)** *Intraprocedural CT of a 72-year-old man during RFA is shown. The tines ⇨ of the umbrella-type probe are noted within the target lesion ➡. A 15-min impedance-based ablation was performed.*

(Left) *NECT obtained 2 months after ablation procedure in this 72-year-old man shows the target lesion ⇨ completely surrounded by the ablation margin ➡.* **(Right)** *Six-month postablation surveillance CT in this 72-year-old man shows near-complete resolution of the previously ablated left lower lobe lesion ⇨; however, a new 1.5-cm lesion ➡ is now seen in the right lower lobe.*

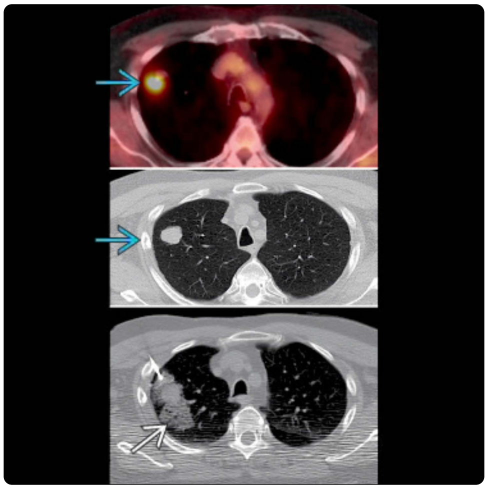


Metastatic Colon Cancer (2-Month Follow-Up)

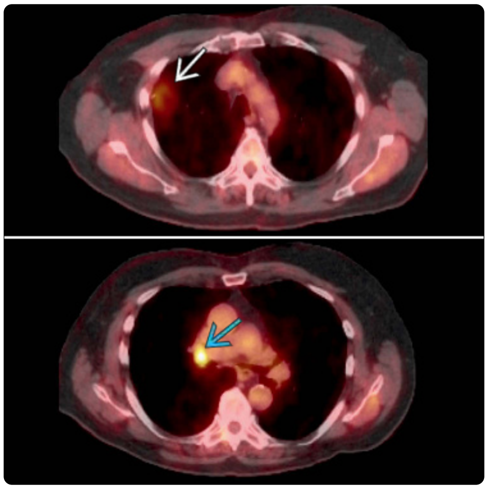


Metastatic Colon Cancer (6-Month Follow-Up)

(Left) *PET-positive 2.3-cm lesion ⇨ is noted in a nonsurgical smoker (top/middle). During probe placement (bottom), alveolar hemorrhage occurred ➡, halted by probe activation due to the coagulative effect of heat-based modalities.* **(Right)** *PET/CT in same patient at 3 months shows decreased FDG uptake in the treated lesion ➡ (top) but new mediastinal uptake ⇨ (bottom). Six-month PET/CT showed no FDG uptake in either lesion, suggesting inflammatory response was mimicking recurrent/metastatic disease.*

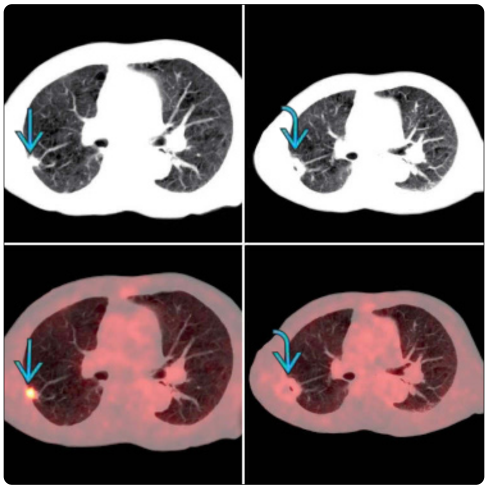


Non-Small Cell Lung Cancer (Alveolar Hemorrhage)

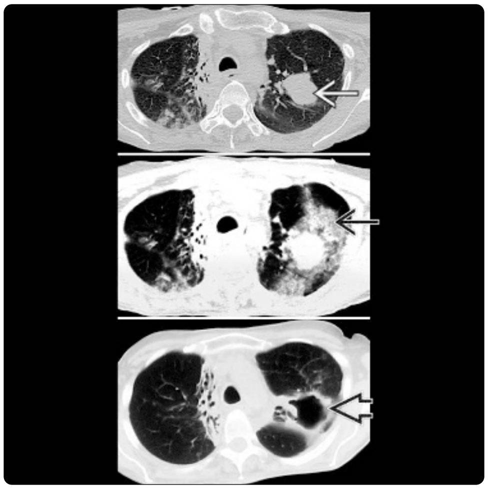


Non-Small Cell Lung Cancer (Follow-Up PET/CT)

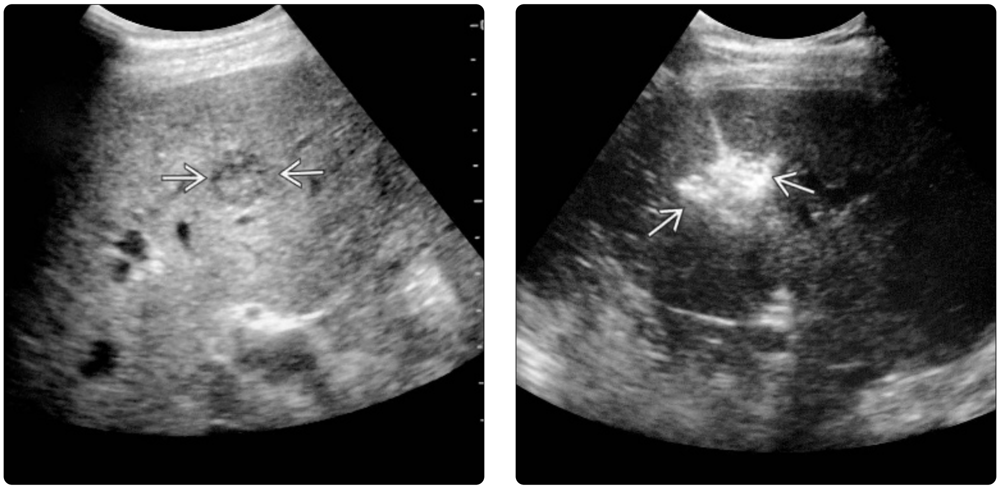
(Left) *A 2-cm, hypermetabolic lung tumor ⇨ underwent RFA. Three-month follow-up PET/CT shows a ring-like lesion with slightly increased metabolism ↪, corresponding to postablation inflammatory changes.* **(Right)** *Though of questionable benefit, multidisciplinary group recommended ablation of a 5-cm melanoma metastasis ➡ (top). Multiple overlapping ablations were complicated by alveolar hemorrhage ⇨ (middle). Three-month follow-up shows complete necrosis and cavitation of the lesion ⇨ (bottom).*



RFA of Primary Lung Cancer (Follow-Up PET/CT)



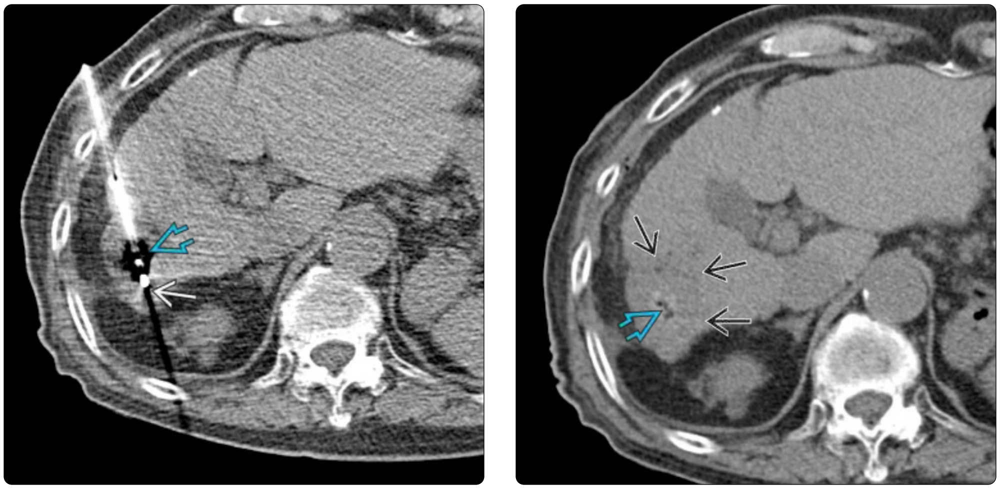
Metastatic Melanoma



Liver Tumor Ablation (US Visualization of Lesion)

Liver Tumor Ablation (US-Guided RFA)

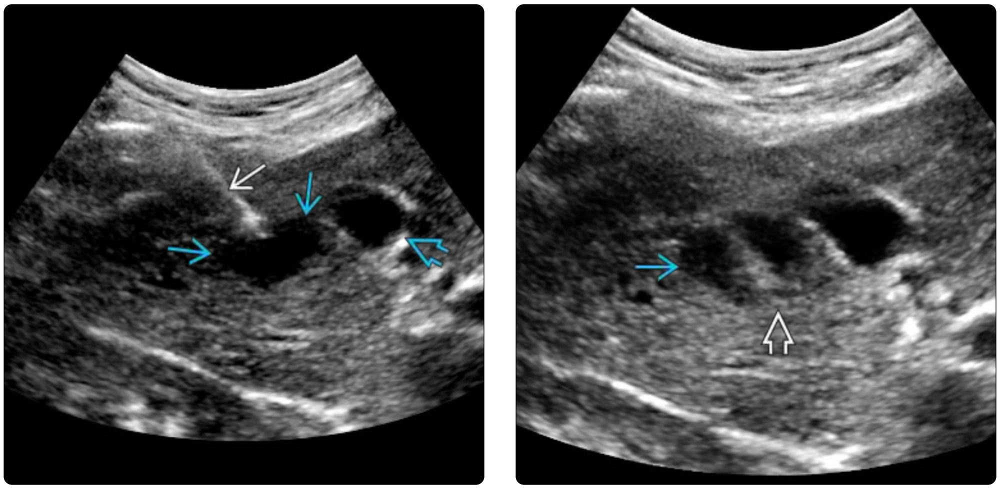
(Left) *An axial Doppler US of a 72-year-old man with monometastatic colorectal cancer to the liver is shown. A single hypoechoic lesion is seen in the left lobe of the liver* ➡*.* **(Right)** *Intraprocedural US during RFA of the lesion is shown. Initial placement of the probe is crucial for a positive outcome. Once ablation is initiated, gas bubble* ➡ *formation obscures visualization and degrades the image, making repositioning difficult.*



CT-Guided MWA of HCC (Probe Positioning & Ablation)

CT-Guided MWA of HCC (Postablation Imaging)

(Left) *A 66-year-old man with cirrhosis and an AFP of 640 was diagnosed with hepatocellular carcinoma (HCC) in liver segment 6. A microwave antenna was placed along the long axis of the lesion with its tip* ➡ *at the distal margin of the mass. Cavitation* ⇨ *is noted, but contrary to US guidance, it does not obscure visualization.* **(Right)** *Postablation CT shows residual air within the tumor site* ⇨*. Relative hypoattenuation surrounding the tumor indicates the ablation zone* ⇨ *extending well beyond the tumor.*

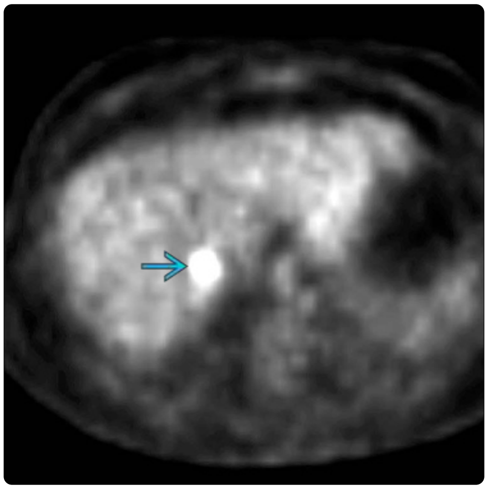


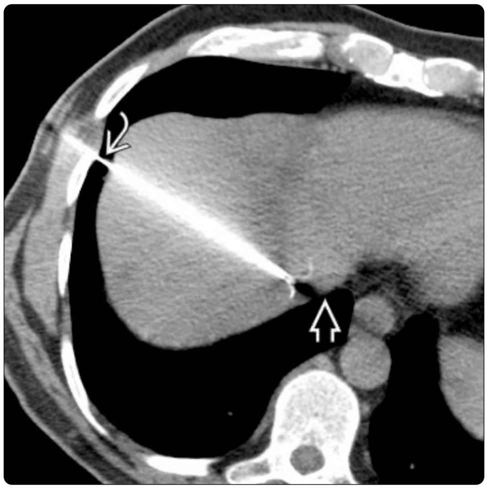
Colon Cancer Metastasis to Liver (US-Guided Probe Placement)

Colon Cancer Metastasis to Liver (Advance Probe Tip to Distal Margin of Lesion)

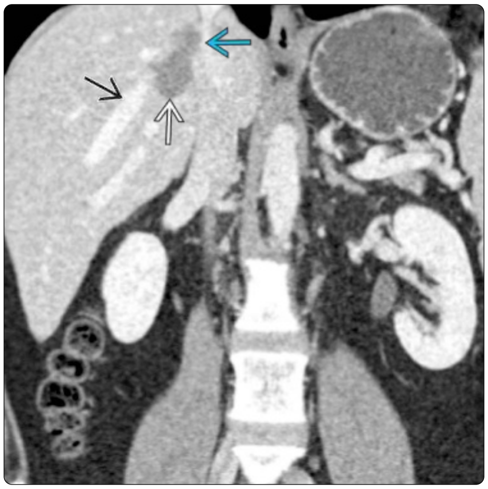
(Left) *A lesion adjacent to the gallbladder* ⇨ *was targeted. Tip of the probe* ➡ *enters the proximal surface equidistant to lesion's perimeter* ⇨*. The gallbladder proximity is concerning for nontarget ablation.* **(Right)** *The microwave antenna is advanced so that its tip* ➡ *is at or just beyond distal margin of target* ⇨*. Irrespective of modality, the ablation margin does not extend more than 2-5 mm beyond the probe tip. Proper initial US-guided probe positioning is paramount; ablation produces gas bubbles that obscure visualization.*

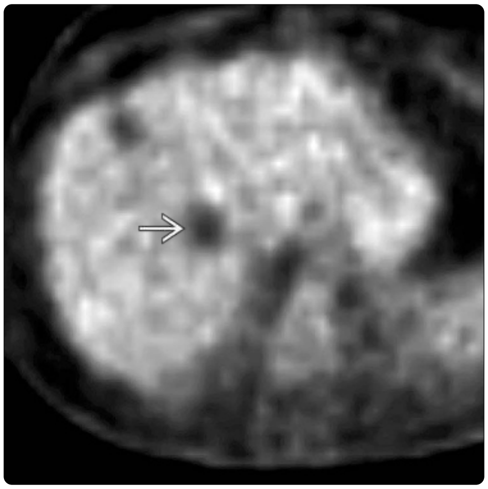
(Left) *An axial PET/CT in a 69-year-old man with cirrhosis is shown. A single HCC abutting the inferior vena cava (IVC) measuring 2 cm was detected on surveillance US. PET/CT shows a hypermetabolic focus ⇨. The diagnosis was confirmed by elevated AFP. Due to proximity to the IVC, it was deemed unresectable.* **(Right)** *An intraoperative CT during RFA is shown. The probe is crossing the lower lung ➡ and traverses a long hepatic segment to reach the lesion near the IVC ➡.*


RFA for HCC (PET-Positive Lesion)

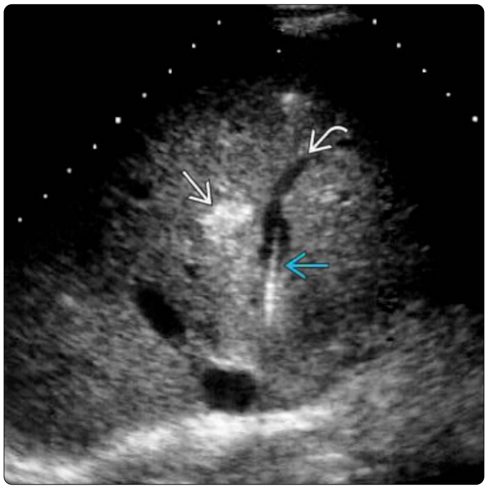

RFA for HCC (Probe Placement & Ablation)

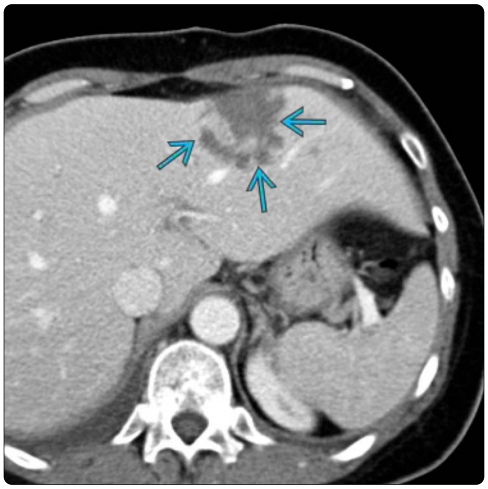
(Left) *A 2-month follow-up coronal CECT shows complete necrosis of the lesion ➡, which is wedged between the IVC ⇨ and right hepatic vein ⇨. Lesions close to large blood vessels have a high risk of recurrence due to the heat sink effect, which prevents effective heating of the lesion.* **(Right)** *A 3-month follow-up PET/CT shows complete lack of uptake by the previously "hot" lesion ➡. Despite this encouraging result, long-term follow-up is required. The proximity to large vessels increases the risk for recurrent disease.*


RFA for HCC (Follow-Up CT)

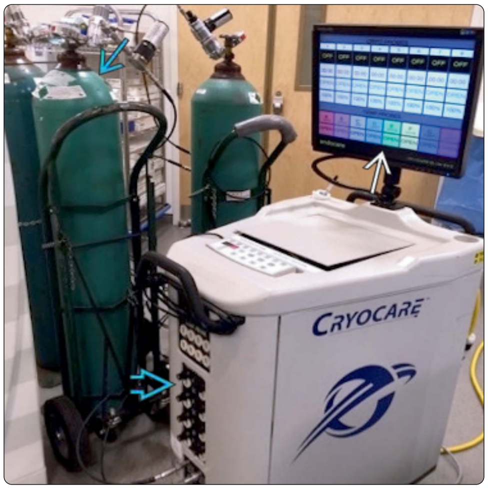

RFA for HCC (Follow-Up PET)

(Left) *A 2-cm colorectal metastasis ➡ abuts the middle hepatic vein ➡. To eliminate heat sink effect, a balloon ⇨ was placed in the middle hepatic vein and inflated to arrest flow during ablation.* **(Right)** *An umbrella-type RFA probe was used to treat a single breast cancer metastasis. The operator rapidly increased the power for faster ablation, but the early charring and dehydration of the tissue around the tines ⇨ prevented further conduction of electricity, resulting in an incomplete treatment zone.*

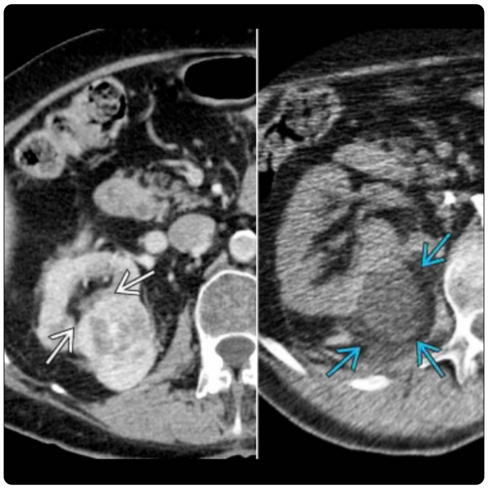

Eliminating Heat Sink Caused by Adjacent Hepatic Vein


Incomplete Ablation Due to Tissue Charring

Cryoablation System

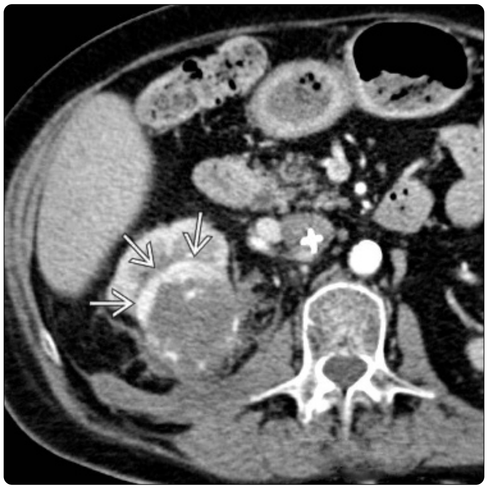


Cryoablation for Renal Cell Carcinoma (Pre- & Postablation Imaging)

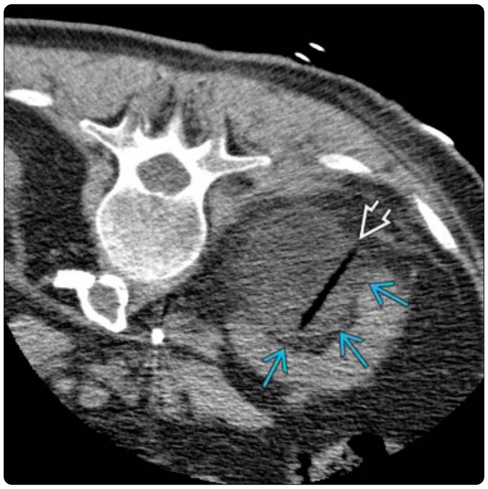


(Left) *Argon and helium gas cylinders are connected to the control unit* ⇨*, and probes connect just above the gas connections* ⇨*. The touch screen* ➡ *allows for monitoring of each probe in use.* **(Right)** *A baseline CT (left) in a 74-year-old woman shows a large mass with margin* ➡ *abutting the hilum. Intraprocedural CT (right) shows the "ice ball"* ⇨ *covering the lesion. Because of high risk for hematuria after ablation, care was exercised not to extend the ablation into the hilum, in retrospect a mistake.*

Cryoablation for Renal Cell Carcinoma (3-Month Follow-Up CT)

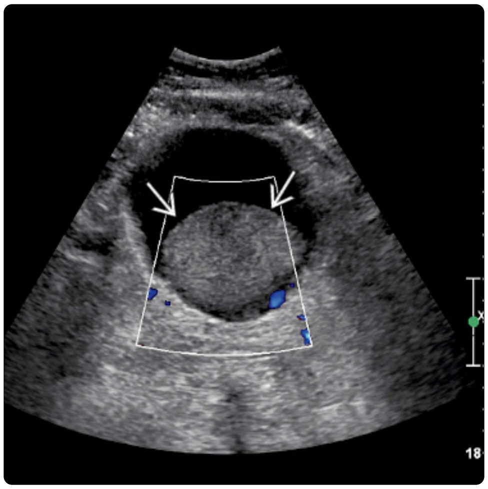


Cryoablation for Renal Cell Carcinoma (Repeat Cryoablation)

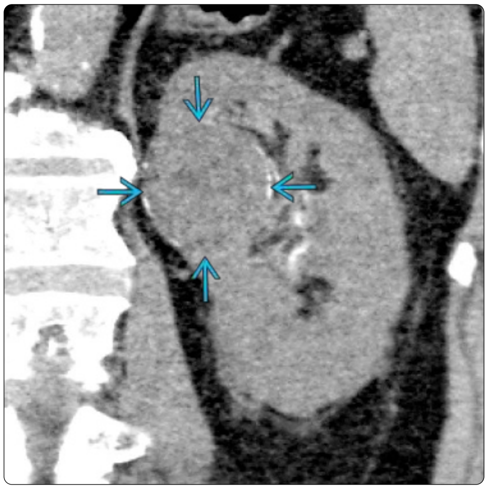


(Left) *A 3-month follow-up CECT shows residual tumor centrally* ➡*, where ablation was intentionally limited to avoid hilar injury.* **(Right)** *Cryoablation was repeated with more extensive ablation into the hilum* ⇨ *to ensure complete tumor necrosis. The "ghost" of the removed cryoablation probe is seen within the still-frozen tissue* ➡*.*

Cryoablation for Renal Cell Carcinoma (US of Bladder)



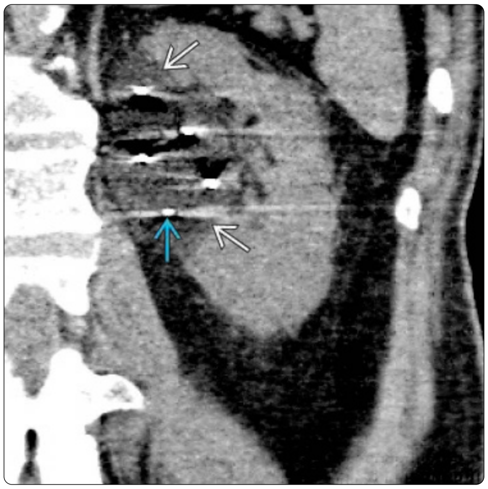
Left Renal Cell Carcinoma Ablation in Right Nephrectomy Patient (Coronal Localizing CT)



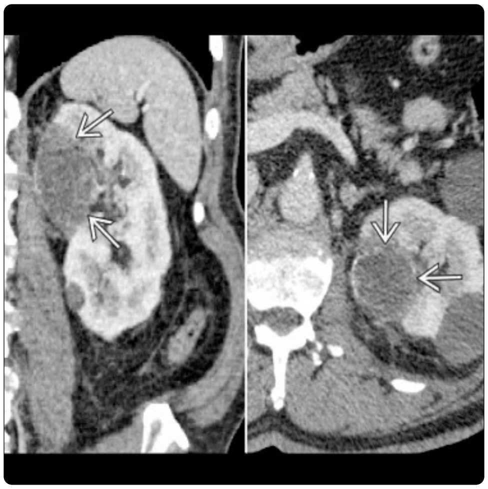
(Left) *While recovering, the patient complained of pelvic pain and inability to void. A bedside US shows a large clot* ➡ *in the bladder. After 3 hours of bladder irrigation, repeat US showed resolution of clot and no hydronephrosis. The patient was discharged home.* **(Right)** *69-year-old man status-post right nephrectomy for treatment of prior renal cell carcinoma presented with a new renal cell carcinoma* ⇨ *in the left kidney.*

(Left) *Five cryoprobes ⇨ were necessary to create an "ice ball" ➡ completely surrounding the target, seen here on an intraprocedural coronal CT. Irrespective of the modality, the operator must ensure adequate margin around the entire target lesion.* **(Right)** *A 3-month follow-up CT (coronal left; axial right) shows a completely devascularized mass ➡ with the remainder of the kidney intact. The patient's function remained stable and did not require hemodialysis despite previous right nephrectomy.*

Left Renal Cell Carcinoma Ablation in Right Nephrectomy Patient (Visualization of "Ice Ball")

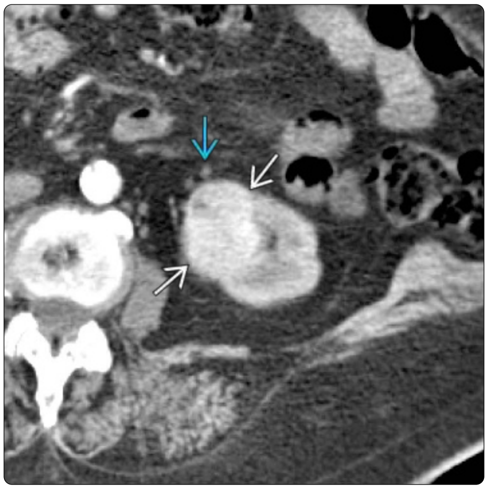


Left Renal Cell Carcinoma Ablation in Right Nephrectomy Patient (Follow-Up CT)

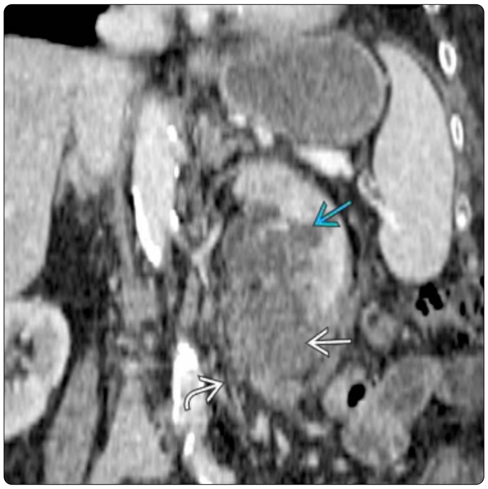


(Left) *A 54-year-old woman with left renal cell carcinoma ➡ underwent cryoablation. The renal cell carcinoma is located in the medial inferior portion of the kidney near the ureter ⇨. No protective maneuver was provided.* **(Right)** *Ten days post ablation, the patient returned with left flank pain. CT shows a devascularized mass ➡. However, there is hydronephrosis ⇨ due to ureteral injury/stricture ↪. A protective double J ureteral stent is recommended when ablation is within 1 cm of ureter.*

Ablation of Renal Cell Carcinoma Near Ureter (Ureter Anterior to Renal Cell Carcinoma)

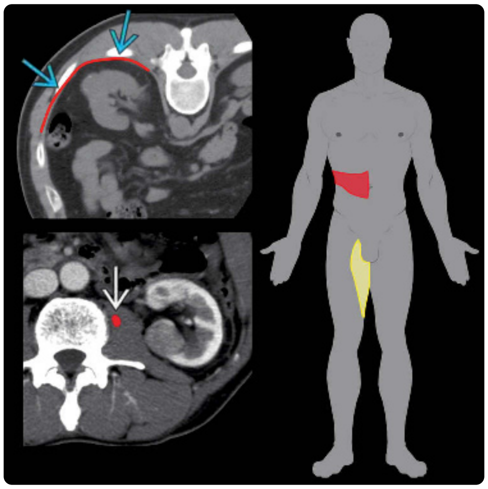


Ablation of Renal Cell Carcinoma Near Ureter (Ureteral Injury Post Cryoablation)

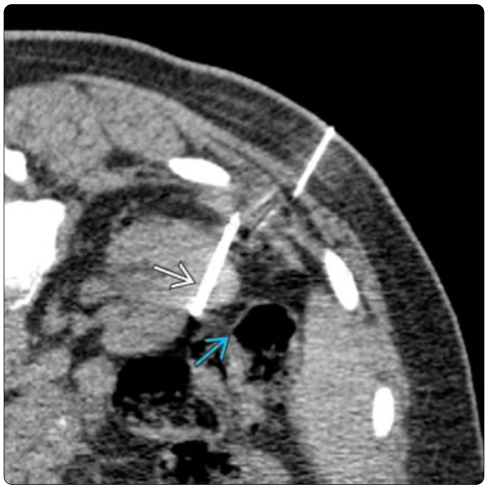


(Left) *The genitofemoral nerve ➡ runs in a craniocaudal direction on the anterolateral surface of the psoas muscle. Injury results in paresthesias in the upper medial thigh (blue area). The intercostal nerve runs under each rib ⇨. Injury results in pain, paresthesias, and muscle laxity in the corresponding anterolateral abdominal wall segment (red area). This may be confused with hernia.* **(Right)** *The ablation probe ➡ has been inserted through the target lesion. The colon ⇨ is very close to the lesion, risking nontarget injury.*

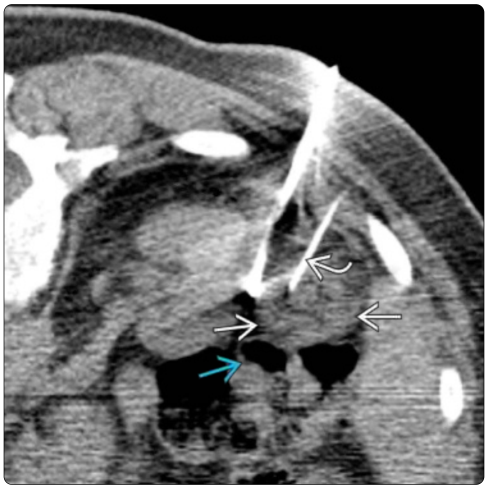
Possible Nerve Injury After Renal Ablation



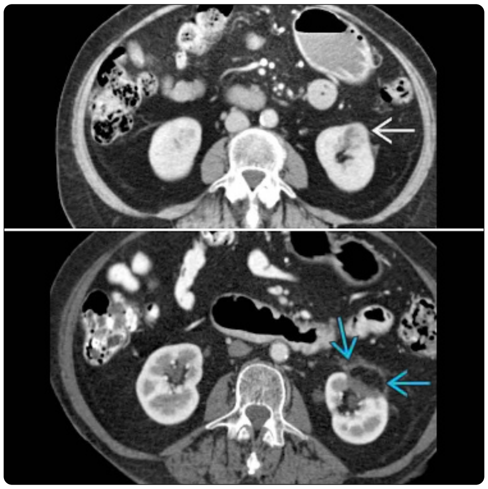
Hydrodissection to Protect Against Nontarget Colon Injury (Probe Placement)



Hydrodissection to Protect Against Nontarget Colon Injury (Colon Displaced)

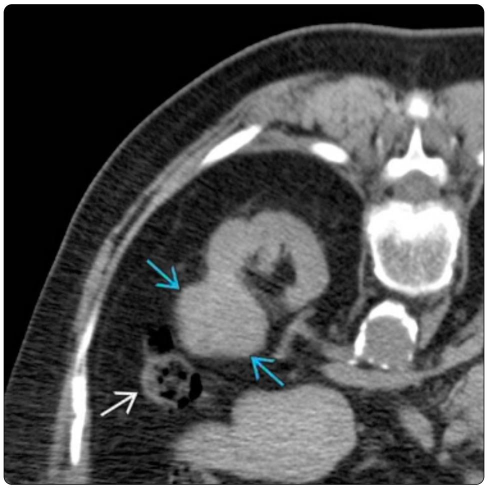


Evolution of Ablated Renal Cell Carcinoma

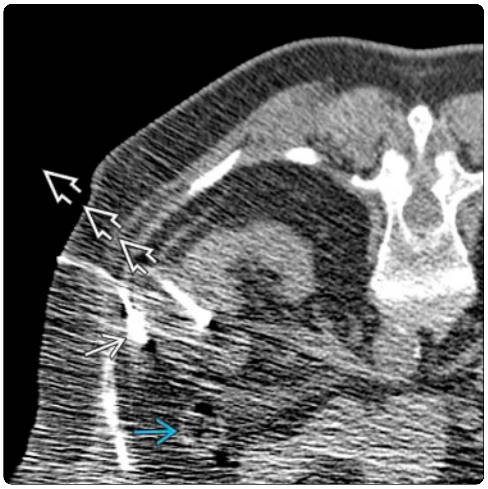


(Left) *A spinal needle ➡ has been placed between the target and the colon. Water injection ➡ has pushed the colon ⇨ to a safe distance from the ablation zone.* **(Right)** *A baseline CT (top) shows a 2.5-cm renal cell carcinoma ➡ prior to ablation. Two-year follow-up CT (bottom) shows disappearance of the mass with a residual fibrous rim ⇨ at the ablation margin. This is a common feature and should not be confused with recurrent disease.*

Mitigating Risk for Nontarget Ablation (Localizing CT)

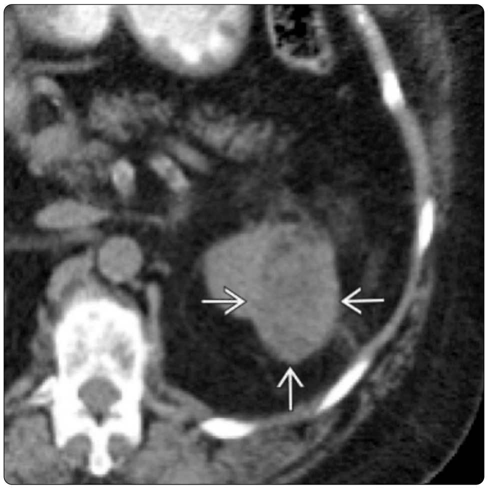


Mitigating Risk for Nontarget Ablation (Hydrodissection & Pulling Lesion)

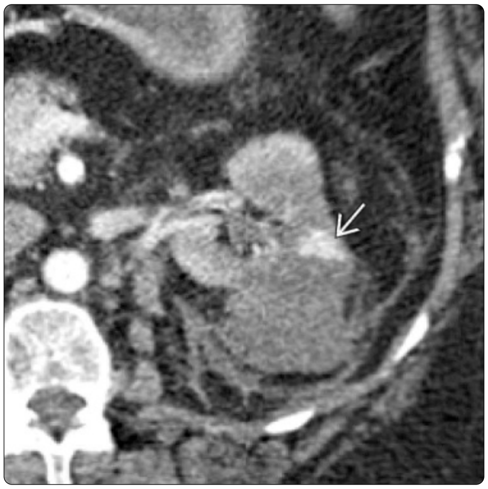


(Left) *55-year-old man with left renal cell carcinoma underwent cryoablation. The descending colon ➡ is precariously close to the target lesion ⇨.* **(Right)** *During cryoablation, a spinal needle ➡ was used to hydrodissect the colon ⇨ away from the lesion. Since the cryoprobe "sticks" firmly to the lesion, it was used to pull the lesion ➡ further away from the colon, a maneuver not possible with heat-based modalities.*

Large Renal Cell Carcinoma (Lesion Localization)



Large Renal Cell Carcinoma (Recurrence on Follow-Up CT)



(Left) *Shown is a 78-year-old woman with renal cell carcinoma who is not a surgical candidate. A large, left-sided renal cell carcinoma ➡ is seen on this baseline CT.* **(Right)** *A 3-month follow-up CT after ablation reveals a focus of enhancement ➡ compatible with residual disease. Repeat ablation can be performed to treat residual disease, which in this case resulted in complete obliteration of future tumor enhancement.*

KEY FACTS

TERMINOLOGY

- Transcatheter arterial chemoembolization (**TACE**)
  - Locoregional treatment for inoperable primary/secondary hepatic malignancies
  - Induces tumor ischemia and provides high/prolonged local chemotherapy concentration
- **Conventional TACE (cTACE)**: Uses Lipiodol as chemotherapeutic carrier agent followed by particulate embolization
- **Drug-eluting bead TACE (DEB-TACE)**: Chemotherapeutic delivery and embolization using beads impregnated with chemotherapeutic agent
- **Bland embolization**: Particulate embolization without chemotherapeutic

PROCEDURE

- Selectively catheterize vessel(s) supplying tumor
- Administer treatment into target vessel with fluoroscopic monitoring to minimize reflux
- Procedural endpoint
  - Stasis or near stasis in vessels supplying tumor with elimination of tumor blush
  - Preserved flow in nonembolized arteries

POST PROCEDURE

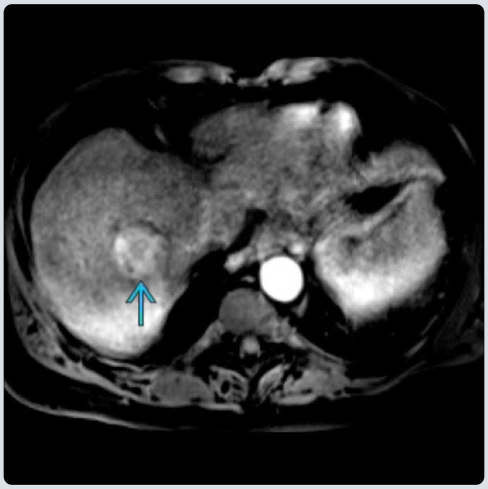
- Monitor and treat postembolization syndrome
- Reassess patient's clinical status ~ 4 weeks after initial treatment
- If patient remains good candidate, plan for TACE of untreated tumor 4-8 weeks after initial TACE

OUTCOMES

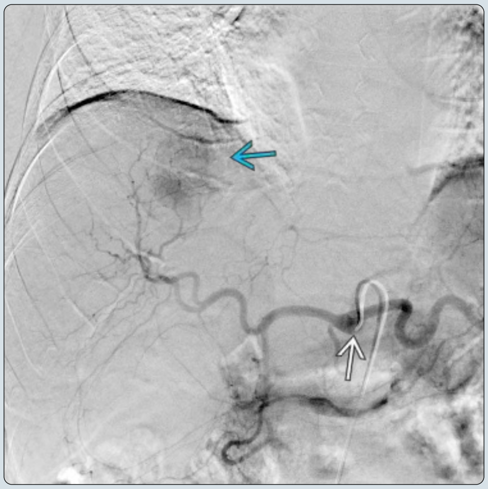
- **HCC**: 2 randomized trials found survival benefit with TACE
- **Neuroendocrine tumor**: High response rates noted with TACE and bland embolization
- **Colorectal cancer**: Single small randomized trial suggests survival benefit with irinotecan DEB-TACE
- **Other malignancies**: Promising results, need prospective trials to confirm benefits of intraarterial therapy

(Left) *Axial T1WI C+ MR shows a right hepatic lesion* ⇨ *with a surrounding capsule & early arterial enhancement, which showed contrast washout on delayed images. The findings are typical of hepatocellular carcinoma (HCC).* **(Right)** *DSA in the same patient with a Simmons-1 catheter* ➡ *in the celiac trunk shows the arterially enhancing HCC* ⇨ *in the right lobe of the liver. Conventional Lipiodol-based chemoembolization (cTACE) was performed after superselective catheterization of the tumor arterial supply using a microcatheter.*

Hepatic Dome HCC (MR)

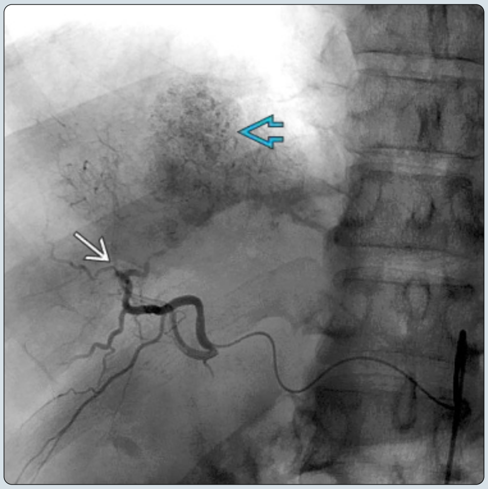


Hepatic Dome HCC (Celiac Angiogram)

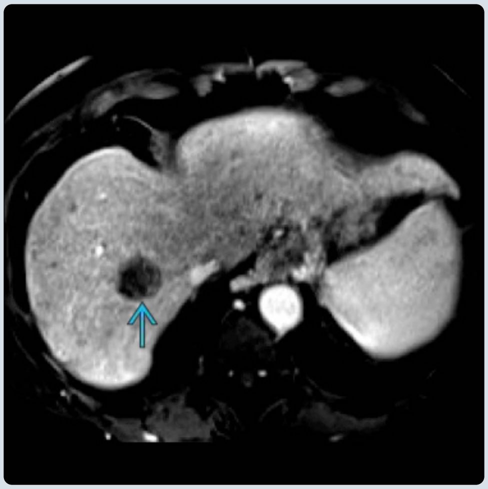


(Left) *An arteriogram following cTACE shows pruning of the embolized right hepatic artery branches* ➡ *with chemolipiodol accumulation within the tumor* ⇨*.* **(Right)** *Contrast-enhanced MR of the abdomen obtained 1 month after TACE shows lack of arterial enhancement within the tumor* ⇨*, indicating a good response to treatment.*

Hepatic Dome HCC (Post cTACE Right Hepatic Angiogram)



Hepatic Dome HCC (Post cTACE MR)



TERMINOLOGY

Definitions

- **Transcatheter liver-directed therapy**
  - Targeted treatment of primary and secondary hepatic malignancies by injecting therapeutic agent via catheter advanced into hepatic artery
  - Includes bland embolization, chemoembolization [conventional and drug-eluting bead (DEB)], and radioembolization
  - Takes advantage of fact that hepatic cancers receive blood supply primarily from hepatic artery, whereas liver parenchyma has dual supply from hepatic artery and portal vein, making it less susceptible to injected therapeutic
- **Transcatheter arterial chemoembolization (TACE)**
  - a.k.a. hepatic arterial chemoembolization
  - Treatment of hepatic tumor by injection of chemotherapeutic agent with or followed by embolic particles
  - 2 subtypes of TACE, conventional TACE (cTACE) and DEB chemoembolization (DEB-TACE), differ primarily in carrier agent for chemotherapeutic
  - Primary antitumor effect is via ischemic necrosis; however, also causes high, prolonged concentration of chemotherapeutic drug within hepatic tumor, which is thought to provide additional antitumor effect
- **cTACE**
  - Uses Lipiodol (iodized fatty acids of poppy seed oil) as carrier agent for chemotherapeutic
  - Aqueous chemotherapeutic solution is emulsified with hydrophobic Lipiodol to create water-in-oil emulsion
    - Chemolipiodol mixture is injected directly into hepatic artery via catheter; it is preferentially retained within abnormal tumor microvasculature relative to that of surrounding liver
    - Chemolipiodol is selectively taken up and retained by tumor cells
    - Chemolipiodol mixture is followed by or mixed with particulate embolic agent to produce tumor ischemia and decrease washout of chemotherapeutic from tumor
- **DEB-TACE**
  - Embolization using beads impregnated with chemotherapeutic agent, such as doxorubicin or irinotecan
  - Embolic beads designed for controlled local delivery of chemotherapeutic drugs with decreased washout into systemic circulation compared with chemolipiodol
    - Beads act as occlusive embolic agents: Ischemic effect
    - Chemotherapy slowly released from beads delivers local, sustained dose of drug: Chemotherapeutic effect
    - Decreased systemic release of drug compared with chemolipiodol appears to cause fewer systemic side effects from chemotherapeutic
- **Bland embolization**
  - Transcatheter arterial embolization using only embolic material without chemotherapy
  - Proponents argue that efficacy of TACE, particularly when treating hypervascular tumors, such as hepatocellular carcinoma (HCC), or neuroendocrine tumor, comes from embolization not chemotherapeutic agent
  - Much less commonly used than TACE as 1st-line therapy for treatment of most primary and metastatic hepatic malignancies
  - Often used as 1st-line therapy in actively bleeding hepatic tumors
  - Often used as 1st-line therapy for benign hepatic lesions, such as unresectable hepatic adenomas

PREPROCEDURE

Indications

- **HCC**
  - Efficacy for treatment of HCC of cTACE over supportive care alone demonstrated by 2 randomized controlled trials and several metaanalysis
  - Barcelona Clinic Liver Cancer (BCLC) staging system is most commonly used system for staging and triaging patients with HCC
    - Stages based on
      - Tumor size and extent
      - Degree of liver dysfunction (Child-Pugh score)
      - General patient functional status [Eastern Cooperative Oncology Group (ECOG) performance status (PS)]
    - Stage 0: Very early stage: 1 HCC < 2-cm diameter
    - Stage A: Early stage: Single HCC or 3 nodules < 3 cm, Child-Pugh A-B, PS 0
    - Stage B: Intermediate stage: Large, multinodular HCC, Child-Pugh A-B, PS 0
    - Stage C: Advanced stage: Portal vein invasion, extrahepatic spread, Child-Pugh A-B, PS 1-2
    - Stage D: Terminal stage: Child-Pugh C, PS 3-4
  - BCLC system recommends TACE only for nonsurgical patients in intermediate stage B; this is controversial, however, and many institutions in USA extend indications for TACE in several situations
    - Stage 0, A, or B patients who are waiting for liver transplantation to prevent tumor from progressing to beyond United Network of Organ Sharing (UNOS)/Milan transplantation criteria while waiting ("bridge to transplant")
      - Milan/UNOS criteria: 1 tumor < 5 cm or up to 3 tumors < 3 cm, no extrahepatic disease, no vascular invasion
      - Treatment of HCC particularly important if expected wait time for transplant is > 6 months
    - Stage C patients who are stage C only because of small-volume, extrahepatic spread, slightly reduced PS 1, or segmental branch portal vein invasion
- **Metastatic neuroendocrine tumor (NET)**
  - Broad category of tumors that includes carcinoid, most commonly arising from bowel, and pancreatic islet cell tumors
  - 1st-line therapy for metastatic NET is surgical resection ± ablation if there is possibility of achieving potentially curative R0 resection

  - Although there are no RCTs of catheter-directed therapy of NET liver metastasis, extremely high response rates of liver metastasis to both TACE and bland embolization has provided strong rationale for treatment of unresectable liver metastasis
    - General indications for treatment
      - Symptoms not controlled by octreotide
      - Disease progression despite treatment with octreotide
      - Excessive tumor burden threatening liver function
- **Metastatic colorectal cancer (mCRC)**
  - 1st-line therapy for metastatic mCRC is surgical resection ± ablation if there is possibility of achieving potentially curative R0 resection
  - For nonsurgical candidates with liver dominant metastasis, current weight of evidence suggests that radioembolization should be 1st-line liver-directed therapy (in combination with systemic chemotherapy)
  - For patients who are not candidates for radioembolization or have failed despite repeated radioembolization, TACE can be offered
    - 1 small RCT suggested improved overall survival with treatment using DEB-TACE with irinotecan-eluting beads (DEBIRI)
  - Limited evidence to support bland embolization over TACE for mCRC
- **Other unresectable hepatic metastases**
  - Cholangiocarcinoma, breast cancer, sarcoma, melanoma/ocular melanoma, renal cell cancer
  - Evidence for treatment with TACE and bland embolization is limited to retrospective studies
    - Can consider for hepatic tumor progression despite systemic treatment
    - Can consider for symptoms related to hepatic tumor bulk

Contraindications

- Extensive extrahepatic disease such that control of liver tumor is unlikely to dictate survival
- Factors suggesting poor baseline liver function and greater risk of dying from liver failure than tumor
  - Hyperbilirubinemia (> 2 mg/dL)
  - Severe underlying cirrhosis: Child-Pugh class C liver disease
  - Liver parenchyma involvement by tumor of > 50%
- Significant portal vein thrombosis without development of sufficient portal-portal collateral flow
  - High risk of posttreatment liver failure or infarct
  - Radioembolization sometimes preferred due to its decreased impact on arterial blood flow
- Significant arterioportal or arteriovenous shunting that cannot be safely reduced during procedure
  - Arterioportal shunting increases risk of postprocedure liver failure/liver infarct
  - Arteriovenous shunting increases risk of embolic bypassing liver and entering pulmonary artery
- Transhepatic intrajugular portosystemic shunt
  - Increased risk of posttreatment liver failure after arterial embolization due to limited portal venous flow to liver
- Poor baseline functional status and inability to recover from procedure
  - ECOG PS scale: Prefer PS 0 or 1
    - 0: Fully active; no restrictions
    - 1: Physically strenuous activity restrictions; ambulatory and able to do light work
    - 2: Ambulatory/self-care capable; unable to do any work activity; up/about > 50% of waking hours
    - 3: Capable of only limited self-care; confined to bed or chair > 50% of waking hours
    - 4: Completely disabled; cannot carry on any self-care; totally confined to bed or chair
    - 5: Dead

Preprocedure Imaging

- **Contrast-enhanced MR or CT**
  - Assess tumor burden
    - Size and location of tumor(s)
    - Disease confined to liver vs. extrahepatic disease
    - Liver parenchyma involvement of < 50%
  - Assess tumor enhancement
    - Strong arterial phase enhancement predicts response to therapy
  - Vascular anatomy
    - Assess for variant hepatic arterial anatomy and arterial supply to tumor(s)
    - Portal vein patency

Getting Started

- Things to check
  - History and physical examination
    - Review tumor type, relevant staging system, and pathological grade
    - Review prior and current systemic oncological treatments
      - Has patient suffered any relevant toxicities, particularly liver related, of systemic treatments?
      - Is patient taking taking bevacizumab (Avastin), and if so, has it been held for 2 weeks prior to procedure?
    - Review prior surgical history as well as plan for future surgeries
      - Is patient potential candidate for curative resection?
      - Is patient potential candidate for transplantation (usually in setting of HCC)?
    - ECOG PS evaluation
      - Can patient tolerate treatment, or will their limited quality of life be worsened by liver-directed treatment?
    - Assess underlying liver function and ability to tolerate locoregional treatment
      - Cirrhotics: Child-Pugh score, MELD-Na score
      - Noncirrhotics: Evaluate markers of liver function and ongoing injury: AST/ALT, bilirubin, albumin level, tumor burden > 50% of liver volume, shrunken fibrotic appearance on cross-sectional imaging, multiple lines of prior systemic chemotherapy
    - Review history for prior surgical bilioenteric anastomosis or biliary stent
      - Very high risk of post TACE infectious complications, such as abscess due to bacterial seeding of biliary tree

            - Requires special pre- and postprocedure antibiotic prophylaxis
            - Consider treatment with less abscess-prone locoregional treatment, such as radioembolization
        - Current medications
            - Particularly any anticoagulants, antiplatelet agents, oral hypoglycemic agents
    - Allergies
        - Particularly to iodinated contrast, relevant antibiotics, and chemotherapeutics
            - If mild contrast allergy, may need to receive premedication per institutional guidelines
            - If severe contrast allergy, may need to use alternative contrast agents (CO_2, gadolinium) or have anesthesiology support for procedure
    - Laboratory parameters
        - Markers of renal function
            - BUN/Cr
        - Markers of bleeding risk
            - International normalized ratio (INR) ≤ 1.5
            - Normal prothrombin time (PT), partial thromboplastin time
            - Platelet count > 50,000/μL
        - Markers of liver function, liver injury, and cholestasis
            - Albumin, bilirubin (direct/indirect), PT/INR
            - AST, ALT, ALK-P
        - Baseline levels of relevant tumor markers for posttreatment comparison
            - HCC: α-fetoprotein
            - Colorectal cancer: Carcinoembryonic antigen
            - NET: Chromogranin A
    - Assess if patient meets institutional guidelines for moderate sedation
        - Typically stop intake of solids 6-8 hours and clear liquids 2 hours prior to start of sedation
        - On day of procedure, can continue to take oral medications as prescribed with sip of water
        - Start intravenous hydration
            - Consider vigorous hydration or sodium bicarbonate drip if renal dysfunction
- Medications
    - Preprocedure prophylactic antibiotics with broad-spectrum activity against gram positives, gram-negative enteric organisms, and anaerobes
        - Example: Cefazolin (1 g) and metronidazole (500 mg)
        - If allergy to penicillin, can replace cefazolin with Bactrim DS (160 mg trimethoprim/800 mg sulfamethoxazole)
    - If bilioenteric anastomosis or biliary stent
        - Prophylaxis with antibiotic regimen with broad-spectrum activity and high degree of biliary excretion
        - Example: Moxifloxacin: 400 mg PO beginning 3 days prior and continuing for 17 days post procedure
    - Intravenous conscious sedation
        - Fentanyl and midazolam typically used
    - Prophylactic antiemetics
        - Ondansetron (16 mg)
        - Dexamethasone (10 mg)
        - Diphenhydramine (50 mg)
- Equipment list
    - Catheters/sheaths
        - 5-Fr vascular access sheath
        - Selective catheters
            - Examples: C-1 or C-2 Cobra, Simmons 1 or 2, Yashiro
        - Coaxial hi-flow microcatheter (2.6-3.0 Fr)
            - Examples: Renegade (Boston Scientific; Natick, MA), Progreat (Terumo; Somerset, NJ), Maestro (Merit Medical; South Jordan, UT)
    - Guidewires
        - 0.035" J-wire/Bentson/hydrophilic angled
        - 0.014-0.018" microwire (used with microcatheter)
            - Examples: Transend (Boston Scientific), Glidewire GT (Terumo)

Chemotherapy/Embolization Agents

- **cTACE**
    - Lipiodol (ethiodized oil)
    - Chemotherapeutic agents (powder form)
        - Most commonly used formulations in USA: Doxorubicin and mitomycin or doxorubicin alone
        - Most commonly used formulation in Asia: Epirubicin
        - No evidence supporting superiority of one chemotherapeutic over another for cTACE
    - Particulate embolization agent
        - Examples: Gelfoam, PVA, Embospheres (Merit Medical): 100-300 μm
- **TACE-DEBs**
    - DEBs
        - Made of negatively charged polymers; various proprietary options
        - Selectively load positively charged chemotherapy through ionic interaction process
            - DC/LC beads (Biocompatibles)
            - HepaSphere microspheres (Merit Medical)
        - In vivo particles release chemotherapeutic in controlled and sustained fashion within tumor/liver
            - Minimizes systemic effects of chemotherapeutic and maximizes local concentration within tumor
            - Decreased postprocedure acute elevations of liver enzymes suggesting reduced liver toxicity compared with cTACE
    - Chemotherapeutic agent
        - Doxorubicin: Most commonly used drug for DEB-TACE of HCC and other hepatic tumors
            - 50-75 mg of doxorubicin per 2 mL of DEBs x 2 vials for total dose of up to 100-150 mg of doxorubicin
            - Premixed doxorubicin solution or powdered form can be used; however, powdered form mixed in 2 mL of sterile water loads more quickly onto bead
        - Irinotecan: Some evidence supporting use of DEBIRI in treatment of mCRC
            - 100 mg of irinotecan solution per 2 mL of DEBs x 2 vials for total dose of up to 200 mg of irinotecan
    - Embolization agent
        - Embolization caused by DEB; no additional embolization agent is usually added

PROCEDURE

Patient Position/Location

- Best procedure approach

  - Common femoral artery access generally preferred

Equipment Preparation

- cTACE
  - Prior to procedure, pharmacy mixes powdered chemotherapeutic with nonionic iodinized contrast agent; sterile water added as needed so that specific gravity (SG) of aqueous solution matches that of Lipiodol (1.28)
    - Example: 8 mL of Omnipaque 300 (iohexol, SG: 1.35) plus 2 mL of sterile water (SG: 1), 50 mg of doxorubicin powder, 10 mg of mitomycin yields SG of ~ 1.28
- DEB-TACE
  - Prior to procedure, pharmacy loads chemotherapeutic agent onto DEBs per manufacturer's instructions
    - Example: Preparation of 1 vial of 100-300 µm of DC Beads loaded with 50 mg of doxorubicin
      - ☐ Mix 50 mg of doxorubicin powder with 2 mL of sterile water to achieve concentration of 25 mg/mL
      - ☐ Remove saline from vial of DC beads and add 2 mL of doxorubicin solution to beads
      - ☐ Agitate beads and then allow at least 45 minutes for drug loading
      - ☐ Once loading complete, expel excess solution from vial to achieve total volume of 2 mL

Procedure Steps

- **General**
  - Review most recent cross-sectional imaging immediately prior to procedure to confirm
    - Tumor number, size, and location
    - Aortic and mesenteric anatomy, including presence of replaced hepatic arteries
    - Arterial supply to tumor (not always clearly visible on cross-sectional imaging)
  - Obtain transfemoral arterial access; place sheath
    - Initial access into artery with 18-gauge single-wall needle or 5-Fr micropuncture set access
    - Place 5- or 6-Fr vascular sheath with flush bag
  - Perform abdominal aortogram with flush catheter
  - Perform superior mesenteric artery (SMA) DSA with appropriate selective 5-Fr catheter
    - Exclude accessory/replaced right hepatic artery (RHA)
    - Obtain delayed DSA during portal venous phase to document portal vein patency
  - Obtain celiac arteriogram with selective 5-Fr catheter
    - Define celiac and common hepatic arterial vasculature
    - Examine left gastric artery for presence of accessory or replaced left hepatic artery (LHA)
  - Use hi-flow coaxial microcatheter for common/proper hepatic DSA
    - Minimizes vasospasm/dissection potential
    - Identify left and right hepatic arteries
    - Identify whether arterial supply to segment IV (left medial segment) arises from LHA or proximal RHA
  - Obtain subselective right and left hepatic DSA as indicated by tumor location
  - Review images: Assess for supply to tumor by looking for tumor hypervascularity on DSA
    - Assess for common accessory supply to liver tumors
      - ☐ **Replaced/accessory RHA**: Origin from SMA
      - ☐ **Replaced/accessory LHA**: Origin from left gastric artery
      - ☐ **Inferior phrenic artery**: Origin from proximal celiac trunk or directly from abdominal aorta; often supplies tumors in hepatic dome
      - ☐ **Internal mammary artery**: Origin from subclavian artery; often supplies tumors in anterior liver, particularly when they are subcapsular
    - Assess for potential sites for nontarget embolization
      - ☐ **Cystic artery**: Usually arises from RHA; if possible, try to avoid as chemoembolization with catheter proximal to branch often results in increased and prolonged postprocedure pain and sometimes chemical cholecystitis, generally self-limited
      - ☐ **Right gastric artery**: Usually arises from common or proper hepatic artery in region of gastroduodenal artery or proximal LHA; chemoembolization can result in symptoms of gastritis; however, this is generally self-limited
      - ☐ **Falciform artery**: Usually arises from LHA; chemoembolization can very rarely lead to anterior abdominal wall pain or skin rash
  - Serially subselect with microcatheter, perform mapping of smallest arterial branches supplying identified tumor(s)
  - Attempt to treat from as selective position as possible to minimize treatment effect on uninvolved tumor
    - When attempting to be super selective, be wary of potentially leaving portion of tumor untreated
    - Make sure entire region of tumor blush seen on nonselective common hepatic artery DSA is also seen on superselective DSA
    - If unsure, consider 3D rotational angiography, if available, or treat from less selective microcatheter position if patient's liver function will tolerate this
    - Sometimes small or hypovascular tumors may not be clearly visible on DSA in which case will need to treat empirically based on expected arterial supply to tumors as suggested on cross-sectional imaging
  - 3D rotational angiography
    - Multiple angiographic images obtained at various projection angles around patient
      - ☐ Most modern flat panel detectors can perform either subtracted or unsubtracted rotational angiography (i.e., cone-beam CT)
      - ☐ Generally for TACE, unsubtracted rotational angiography preferred as this will highlight parenchyma and tumor vascularity
      - ☐ Can manipulate rotational angiographic images to identify tumoral arterial supply
      - ☐ Can utilize reconstructed cross-sectional tomographic images to assess whether entire tumor will be treated when in superselective microcatheter position
- Administration of chemoembolic material
  - Inject in nonforceful, pulsatile manner to minimize potential for reflux
    - Administer into target vessel under fluoroscopy; confirm antegrade flow toward tumor
  - Intraarterial lidocaine may be given before or between embolic aliquots to reduce intra- and postprocedure pain
  - Procedural endpoint

    - Near stasis in all identified pedicles supplying tumor with elimination of tumor blush
    - Preservation of flow in nontargeted lobar or segmental arteries
- **cTACE**
  - 10 mL of aqueous chemotherapy solution prepared prior to case by pharmacy
  - Chemotherapy solution emulsified with 10 mL of Lipiodol (lipophilic)
    - Usually use slightly > 1:1 volume ratio of Lipiodol to chemotherapy solution
    - Swish through 3-way stopcock 20-30 times to create chemolipiodol emulsion
    - Produces water-in-oil chemolipiodol emulsion with droplets of aqueous chemo surrounded by continuous phase of oil
  - Inject chemoembolization emulsion via hi-flow microcatheter into tumor-containing region of liver
    - Inject small aliquots of emulsion at a time, observing flow with each injection
    - Consider stopping chemolipiodol injection if significant slowing of blood flow is noted to allow for administration of particulate embolic agent
  - Chemolipiodol administration is followed by particulate embolic agent
- **DEB-TACE**
  - DEBs loaded with chemotherapeutic agent prior to case by pharmacy
  - During procedure, vial of DEB is mixed with nonionic contrast to provide visibility during injection
  - DEBs injected slowly in small aliquots
- **Bland embolization**
  - Start with vial of smallest particles; suspend embolic agent in contrast/saline mixture
  - Similar to DEB-TACE, inject in nonforceful, pulsatile manner to minimize potential for reflux
  - If continued antegrade flow after 1 vial, some will proceed to vial of next larger size particle
  - End-point of embolization is near-stasis or stasis in targeted vessels without evidence of tumor blush on angiogram
- **Combining TACE/bland embolization with percutaneous ablation**
  - Consider combining arterial embolization with percutaneous heat-based ablation (microwave or RFA)
    - Can be beneficial for tumors that are at upper size limit for percutaneous ablation alone (4- to 6-cm diameter)
    - Decreases arterial "heat sink" effect for ablation by reducing blood flow to tumor and surrounding liver
    - Heat may increase cytotoxicity of chemotherapy
      - Ablation usually performed next day
    - Performed with curative intent; goal is 100% tumor death

Alternative Procedures/Therapies

- Radiologic
  - Radioembolization
  - Radiofrequency ablation
- Surgical
  - Liver transplant
  - Surgical resection

POST PROCEDURE

Things to Do

- Admission to hospital overnight
  - Overnight observation is commonly practiced; however, some IRs perform DEB-TACE as outpatient procedure due to its decreased postembolization side effects
  - Provide symptomatic control of postembolization syndrome, if present
    - Provide pain control with IV narcotics ± patient-controlled anesthesia pump
    - Administer antiemetics, such as ondansetron (Zofran) or perchlorpromazine, as necessary
    - Administer antiinflammatories, such as ibuprofen, as necessary
  - Monitor arterial access site for bleeding, hematoma, pulse loss
  - Continue prophylactic IV antibiotics for 24 hours
- Discharge following day
  - Must confirm adequate PO fluid intake, satisfactory pain control with oral narcotics, and ability to urinate and ambulate

Post Procedure Imaging and Clinical Assessment

- If remaining untreated tumor (e.g., contralateral hepatic lobe)
  - Reassess patient's clinical status ~ 4 weeks after initial treatment
    - Assess PS, review liver function tests, and evaluate for hematologic or renal toxicity
  - If patient remains good candidate for locoregional therapy, plan for TACE of untreated tumor 4-8 weeks after initial TACE
  - If patient is no longer good candidate for locoregional therapy, delay additional treatment and follow until status improves
- If all areas of tumor have been treated with TACE, plan for clinical and imaging assessment ~ 4 weeks after last treatment
  - Assess treatment response with contrast-enhanced MR or CT and restage viable tumor
    - After cTACE, MR is preferred because radiodense Lipiodol within tumor can obscure CT contrast enhancement
    - If no areas of viable tumor on imaging (complete imaging response), schedule for follow-up imaging and clinic visit in ~ 3 months
    - If areas of continued tumor viability
      - Consider whether areas of tumor viability could be secondary to undertreated hepatic branches on initial TACE
      - Consider whether areas of tumor viability could be secondary to aberrant or extrahepatic arterial supply

OUTCOMES

Complications

- Most feared complication(s)
  - Liver failure (< 2% of cases)

    - Hepatic insufficiency
    - Hepatic infarction
- Immediate/periprocedural complication(s)
  - Access site complications
  - Nontarget embolization
  - Postembolization syndrome: Fever, pain, nausea
    - Expected posttreatment outcome
      - Tumor cells lyse; release intracellular toxins into bloodstream; toxins cause symptoms
      - Usually subsides in 24-72 hours; may be prolonged
  - Renal insufficiency
- Delayed complication(s)
  - Hepatic abscess
    - Incidence of < 1% in patients with competent sphincter of Oddi
    - Incidence of > 25% in patients with incompetent sphincter of Oddi without adequate pre-/postprocedure antibiotic prophylaxis
    - Effectively managed with percutaneous drainage
    - Need to differentiate abscess from typical benign postembolization imaging appearance
      - Immediate postembolization tumor may appear as low-density lesion with scattered gas bubbles likely introduced via catheter during embolization
      - Abscess occurs at least 7-10 days after treatment with new development of fever and elevated white blood cell count
  - Chemical cholecystitis
    - Secondary to TACE being performed with catheter proximal to origin of cystic artery
    - Presents with findings often identical to infectious acute cholecystitis with fever, RUQ pain, and positive HIDA scan
    - Almost always resolves on own without surgery; however, pain can sometimes last for months
  - Biliary stricture/necrosis
    - Will sometimes lead to biliary dilatation or bilomas
    - Generally does not require invasive treatment unless signs of infection

Controversies

- What is ideal chemotherapeutic for TACE?
  - No consensus on most efficacious chemotherapeutic choice; studies comparing different cytotoxic agents have shown no difference in survival
- Is chemotherapeutic necessary for cTACE?
  - 1 metaanalysis showed survival benefit with cTACE vs. supportive care but not with embolization alone; superiority of cTACE over bland embolization, however, has not been definitively demonstrated
- What is ideal embolic for cTACE?
  - No data to support one particulate agent over another
- Is DEB-TACE superior to cTACE?
  - Data in HCC appears to show decreased postprocedure side effects with DEB-TACE but no difference in overall survival; data in noncirrhotics, such as NET, suggests increased risk of biliary complications with DEB-TACE

Expected Outcomes

- **HCC**
  - 2 randomized trials and several metaanalysis have found overall survival benefit with cTACE in treatment of HCC
  - Randomized data and metaanalysis suggest improved survival with cTACE over bland embolization; however, strong evidence for this is not present
  - Randomized data has suggested similar survival benefit of DEB-TACE compared with cTACE with reduced postembolization syndrome
- **CRC**
  - One small randomized trial showed improved median survival with DEBIRI over systemic chemotherapy alone
  - Studies with cTACE have generally been retrospective and without control groups; report overall survivals of 9-14 months after chemoembolization in salvage setting
- **NET**
  - High response rates seen with cTACE, DEB-TACE, and bland embolization
  - No randomized data comparing 3 treatments

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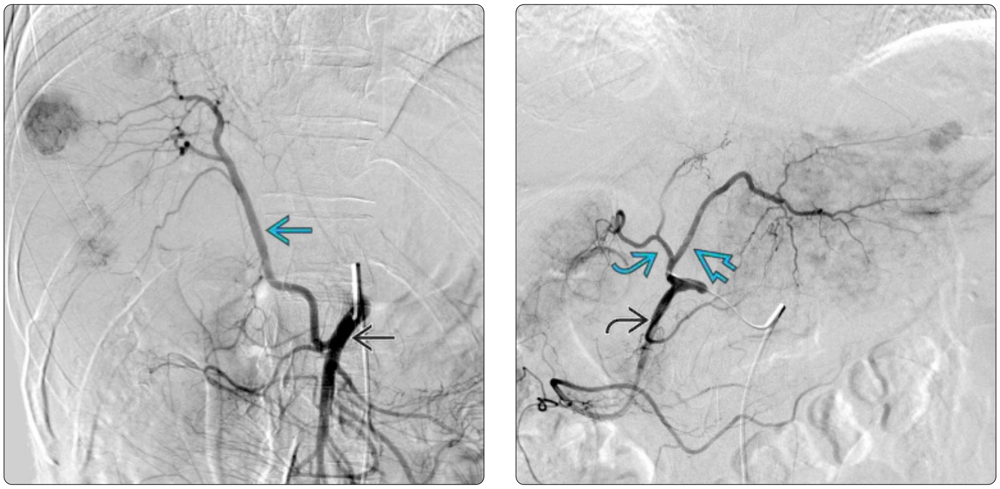
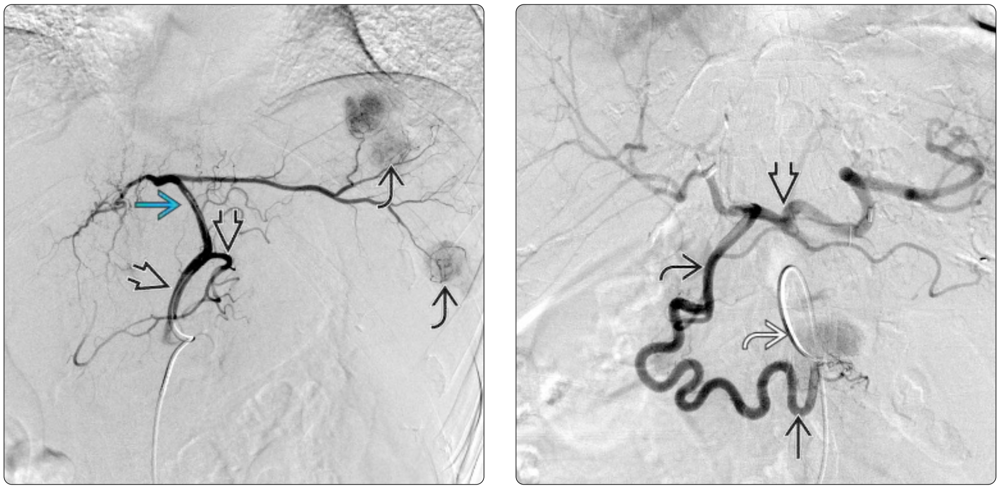


Variant Vascular Anatomy: Replaced Right Hepatic Artery

Variant Vascular Anatomy: Left Hepatic Artery

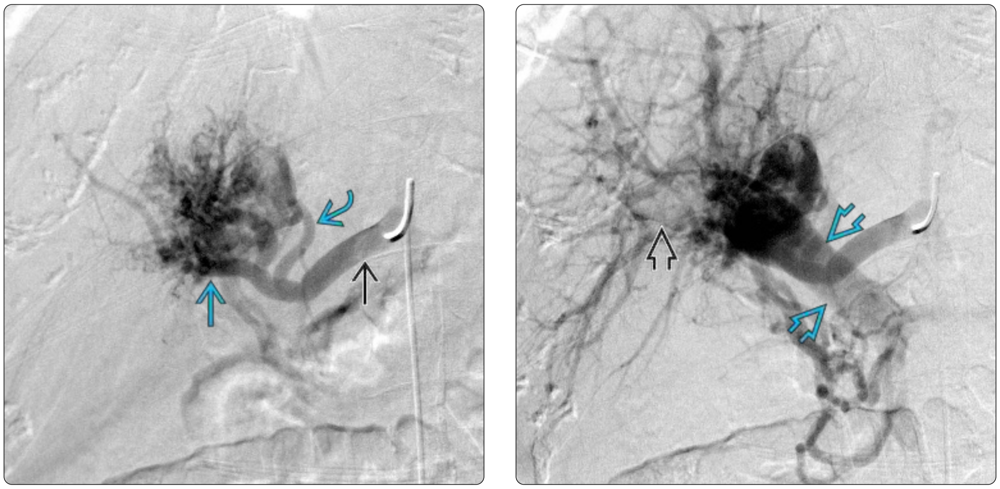
(Left) *A 51-year-old man with hepatitis C-induced cirrhosis and multifocal HCC underwent palliative TACE. Superior mesenteric angiogram* → *revealed a replaced right hepatic artery* → *supplying multiple tumors within the right hepatic lobe.* **(Right)** *DSA from the proper hepatic arteriogram in same patient lacks the right hepatic artery takeoff as is expected with the artery replaced to the SMA. Left hepatic artery medial* ↷ *and lateral* ⇨ *branches arise from a common left hepatic artery. Note gastroduodenal artery (GDA)* ↷*.*



Variant Vascular Anatomy: Accessory Left Hepatic Artery

Celiac Origin Occlusion: TACE via Pancreaticoduodenal Catheterization

(Left) *DSA of the left gastric artery in the same patient* ⇨ *reveals an accessory left hepatic artery* → *into which a microcatheter has now been advanced. Cirrhosis has resulted in significant left lobe hypertrophy, containing HCC foci* ↷*.* **(Right)** *In this patient with occlusion of the celiac artery origin, DSA via a Cobra catheter* ➡ *advanced through the SMA promptly opacifies the GDA* ↷ *and celiac artery* ⇨ *territories. Subsequently, a microcatheter traversed the enlarged pancreaticoduodenal artery* →*, and right hepatic TACE was performed.*

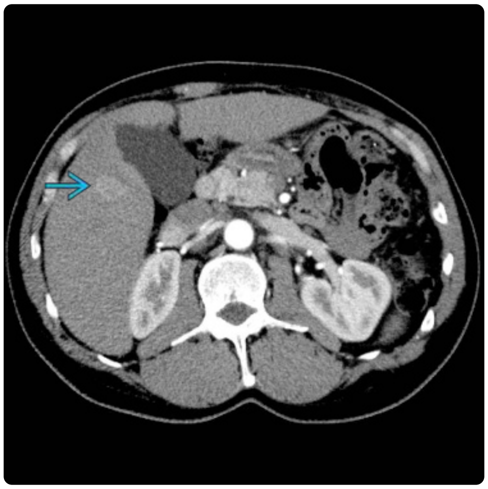


Arterioportal Shunt: Early Arterial Phase of Common Hepatic Arteriogram

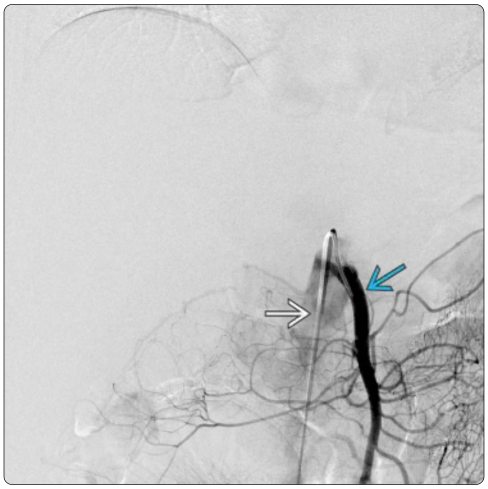
Arterioportal Shunt: Late Arterial Phase of Common Hepatic Arteriogram

(Left) *A 67-year-old man with a large hilar HCC presented for DEB-TACE. Common hepatic* → *DSA via a Simmons-1 catheter shows rapid uptake to the mass from right* → *and left* ↷ *hepatic arteries.* **(Right)** *Almost immediately, filling of the portal vein* ⇨ *occurred, consistent with an arterioportal shunt. Small shunts can at times be blocked with Gelfoam slurry prior to TACE. Large shunts may prevent TACE from proceeding. Additionally, in this case, a filling defect* ⇨ *within right portal vein could represent tumor thrombus.*

Step-by-Step: cTACE (Preprocedure Cross-Sectional Imaging)

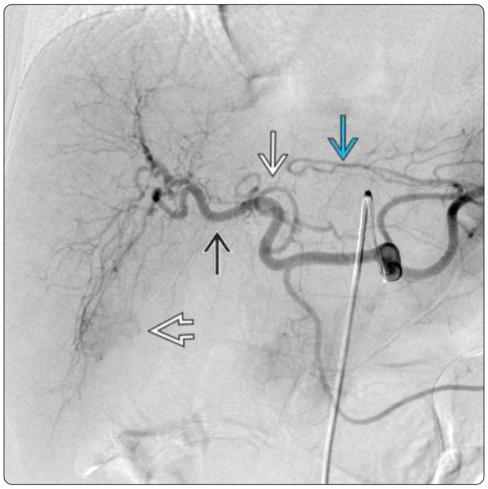


Step-by-Step: cTACE (SMA Angiogram)

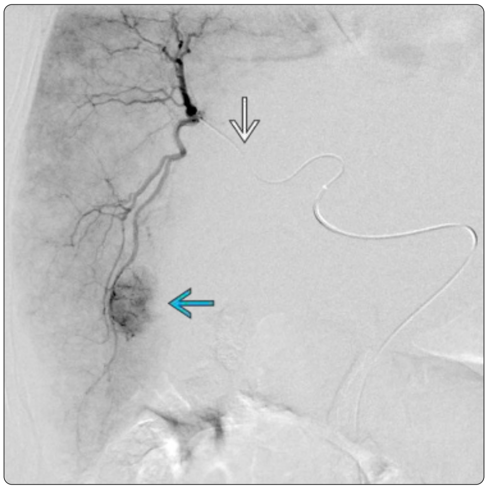


(Left) *Axial CT of the liver shows a arterial enhancement of a 2-cm HCC in the right lobe segment 5 ⇨. A smaller suspicious lesion is present at the hepatic dome (not shown). The patient has HVC cirrhosis and is referred to IR for TACE as a bridge to transplantation.* **(Right)** *A selective SMA angiogram with a Simmons-1 (S1) catheter shows classic mesenteric anatomy without any replaced or accessory hepatic branches to the SMA ⇨. Reflux of contrast into the aorta ➡ confirms that the proximal SMA has been adequately imaged.*

Step-by-Step: cTACE (Celiac Angiogram)

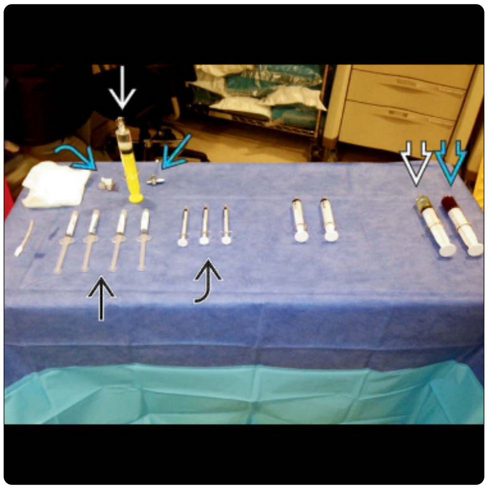


Step-by-Step: cTACE (Selective Right Hepatic Arteriogram)

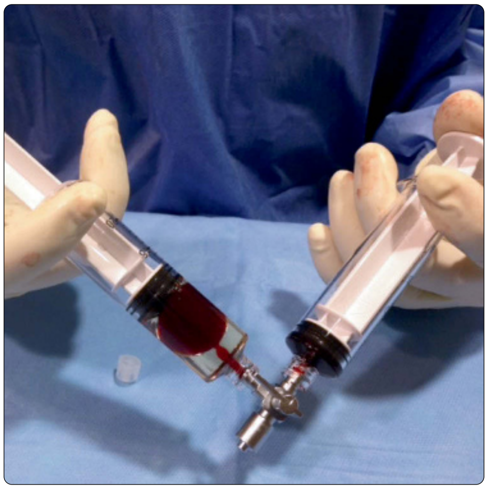


(Left) *A celiac angiogram shows the hepatic arterial anatomy. Visualized are the left hepatic artery ➡, the right hepatic artery ⇨, and an accessory left hepatic artery ⇨ arising from the left gastric artery. Tumor blush in the inferior right hepatic lobe is faintly visualized ➡.* **(Right)** *The right hepatic artery has been subselected with a microcatheter ➡. A selective angiogram clearly demonstrates tumor blush in the inferior right hepatic lobe ⇨. The additional smaller lesion at the hepatic dome is not clearly visualized.*

Step-by-Step: cTACE (Embolization Table)

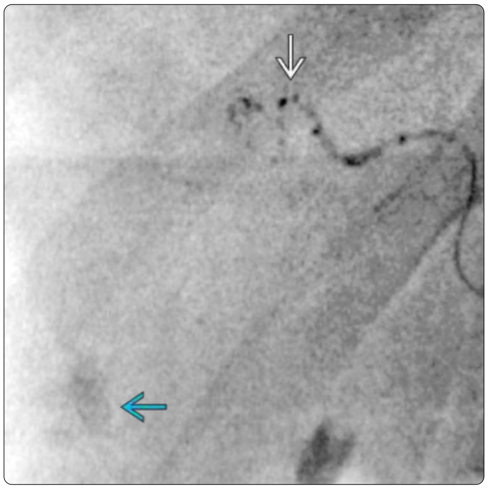


Step-by-Step: cTACE (Creation of Chemolipiodol Emulsion)

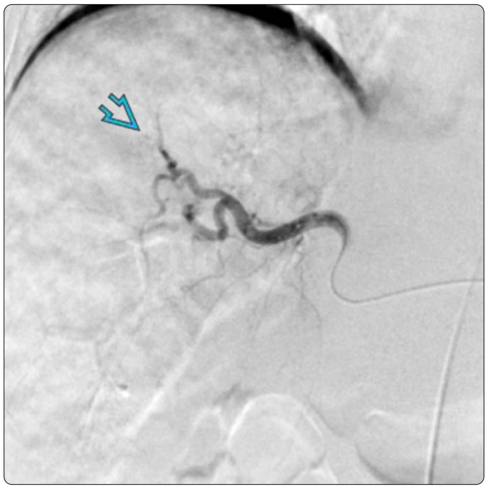


(Left) *On the embolization table are Embospheres (100-300 µL) ➡, 10 mL of Lipiodol ➡, 10 mL of chemotherapeutic solution ⇨, aliquots of lidocaine ⇨, metal 3-way stopcock ⇨ for mixing the chemolipiodol, plastic 3-way stopcock for administering Embospheres ↪, and 1-mL polycarbonate syringes for administering the chemolipiodol emulsion ↪.* **(Right)** *The Lipiodol and chemotherapy are emulsified by repeatedly and rapidly exchanging the contents of the 2 syringes through the metal 3-way stopcock.*

Step-by-Step: cTACE (Administration of Emulsified Chemolipiodol)

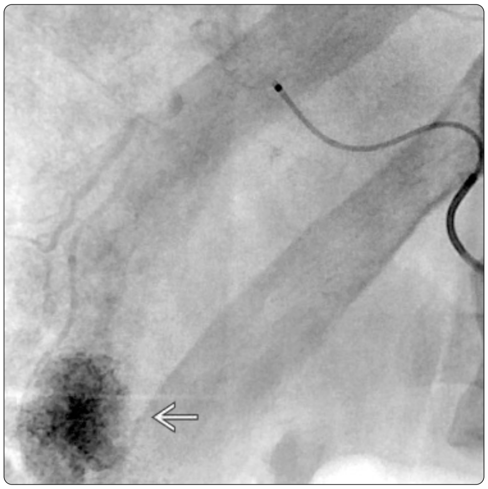


Step-by-Step: cTACE (Post Embolization Right Hepatic Angiogram)

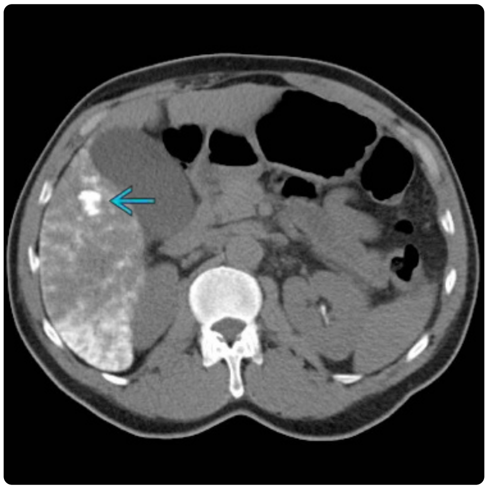


(Left) *The emulsion is administered via the microcatheter using the 1-mL polycarbonate syringes. Droplets of chemolipiodol flow through the artery* ➡. *Faint uptake of chemolipiodol is noted within the tumor* ⇨. **(Right)** *After administration of chemolipiodol and Embospheres, a postembolization angiogram shows near stasis with the classic pruned tree appearance to the arterial branches* ⇨.

Step-by-Step: cTACE (Post Embolization)

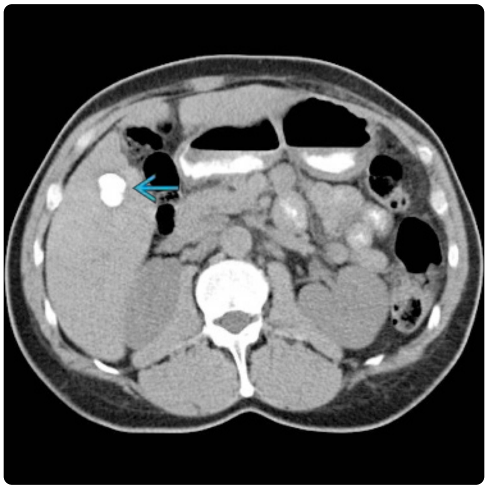


Step-by-Step: cTACE (Post TACE CT)

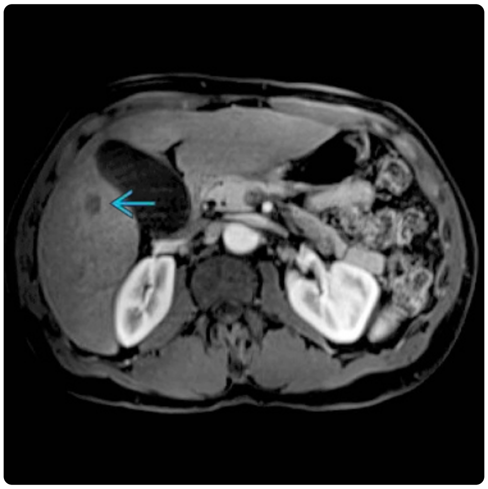


(Left) *Post cTACE spot film taken of the liver shows dense chemolipiodol accumulation within the inferior right hepatic lobe tumor* ➡. *This appearance generally predicts a good response.* **(Right)** *CT of the liver obtained the evening after TACE confirms dense chemolipiodol uptake within the tumor* ⇨. *Chemolipiodol is also noted elsewhere within the liver in the embolized arterial distribution.*

Step-by-Step: cTACE (1 Month Post TACE)



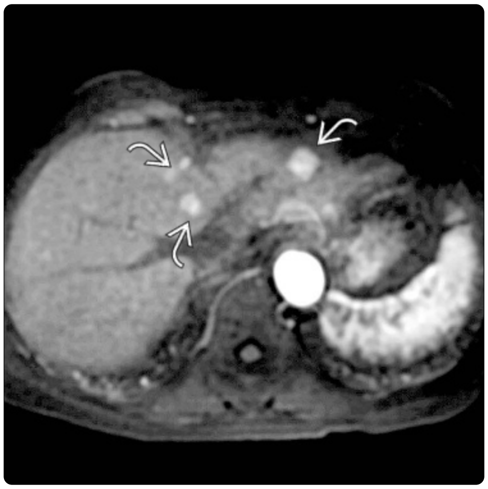
Step-by-Step: cTACE (1 Month Post TACE)



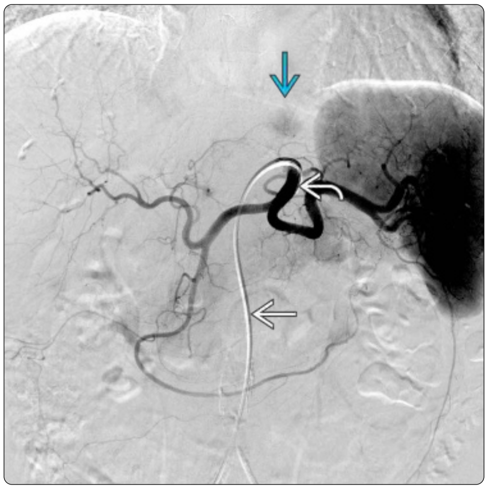
(Left) *Inferior cut of a noncontrast chest CT obtained 1 month later shows continued dense Lipiodol uptake within the HCC* ⇨. *The chemolipiodol has been completely cleared in the surrounded liver by specialized macrophages (Kupffer cells).* **(Right)** *A contrast (Eovist)-enhanced MR of the liver obtained 1 month after cTACE shows no arterial enhancement of the treated HCC, indicating a complete response* ⇨.

(Left) *Axial arterial-phase T1WI C+ MR obtained in a 62-year-old woman with known HCC shows multiple areas of contrast enhancement ➦ involving both hepatic lobes. These imaging findings are consistent with multifocal HCC.* **(Right)** *Anteroposterior DSA obtained with a Cobra catheter ➡ selectively positioned in the celiac trunk ➦ demonstrates conventional arterial anatomy. The tumor in the left hepatic lobe ⇨ is well seen in the arterial phase, confirming hypervascularity.*

DEB-TACE: Pretreatment Imaging (Multifocal HCC on MR Imaging)

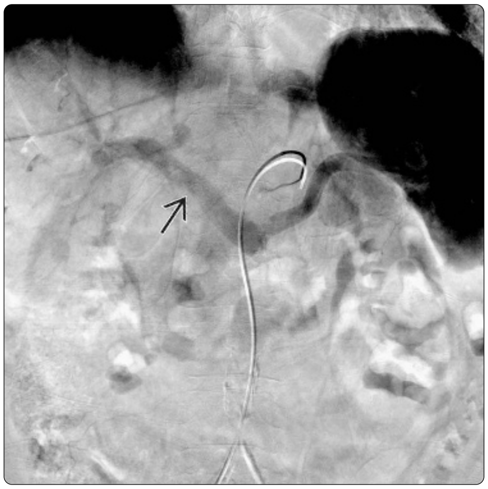


DEB-TACE: Pretreatment DSA (Selective Celiac Arteriography)

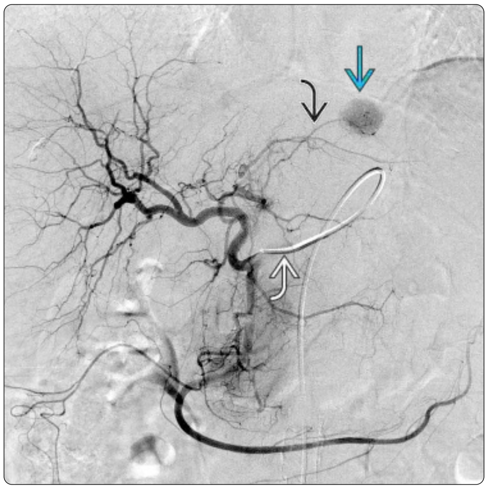


(Left) *Delayed-phase imaging of the celiac arteriogram demonstrates a patent portal vein →. This is important to confirm as arterial embolization without sufficient portal flow significantly increases the risk of liver infarct and hepatic failure.* **(Right)** *The 5-Fr Cobra catheter has been advanced into the distal common hepatic artery ➦, and repeat DSA was performed. The target lesion ⇨ in the left hepatic lobe appears to be supplied by branches ↪ arising from the left hepatic artery.*

DEB-TACE: Pretreatment DSA (Portal Venous Phase Imaging)

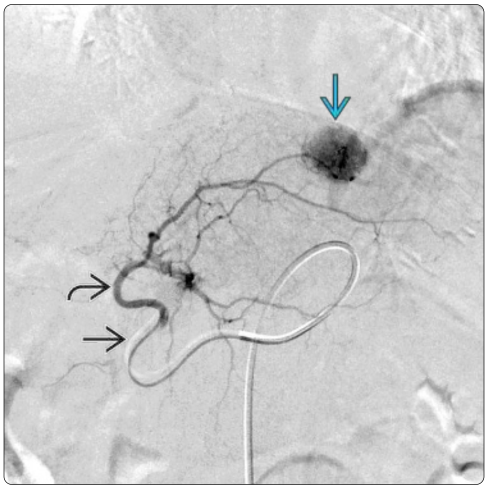


DEB-TACE: Pretreatment DSA (Selective Hepatic Arteriography)

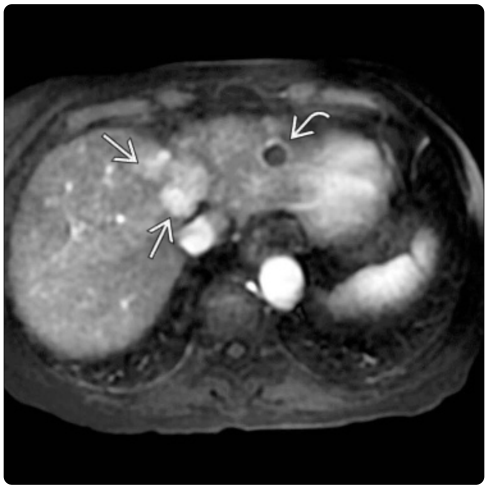


(Left) *Coaxial microcatheter → has been advanced into the left hepatic artery ↪ and a superselective DSA was performed, showing the arterial supply to the tumor ⇨. Patient underwent TACE treatment with DEBs from this location.* **(Right)** *Axial arterial-phase T1WI C+ MR obtained as a follow-up 4 weeks after TACE shows lack of contrast enhancement ➦ in the lesion, consistent with a successful treatment. The patient will return for chemoembolization of the untreated lesions in the right lobe ➡, which appear to have grown in the interim.*

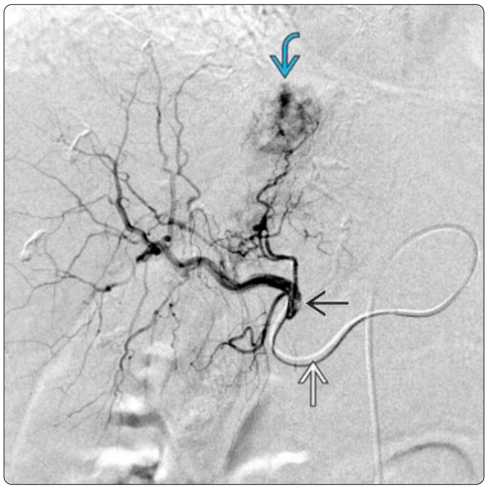
DEB-TACE: Pretreatment DSA (Superselective Hepatic Arteriography)



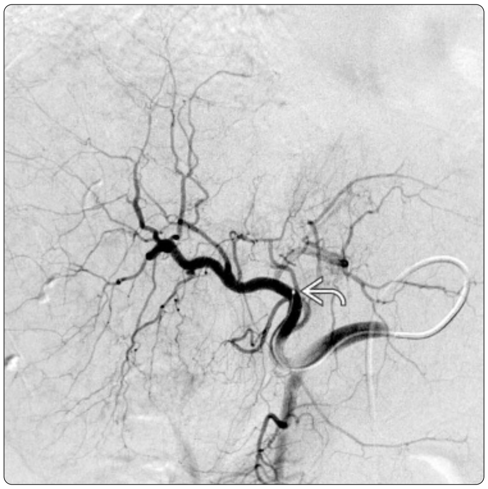
DEB-TACE: Posttreatment Imaging (Lesion Nonenhancement on MR)



DEB-TACE: 2nd Stage (Selective Hepatic Arteriography)

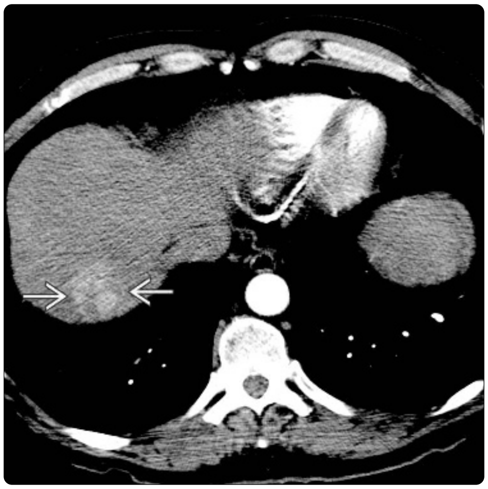


DEB-TACE: 2nd Stage (Post Treatment)

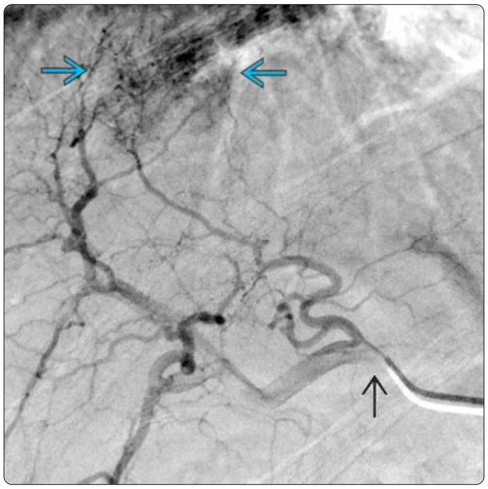


(Left) *The same patient returned for treatment of the right hepatic lesions. Selective segmental right hepatic ⇨ DSA shows a microcatheter ➡ selectively positioned in the arterial supply to the tumor ↪ in hepatic segment IV. The patient underwent treatment with TACE-DEB from this position.* **(Right)** *Selective right hepatic DSA via the microcatheter ↪ immediately after delivery of drug-eluting embolic beads shows elimination of tumor enhancement, consistent with a successful treatment.*

TACE as Bridge to Transplantation (Initial CECT Evaluation)

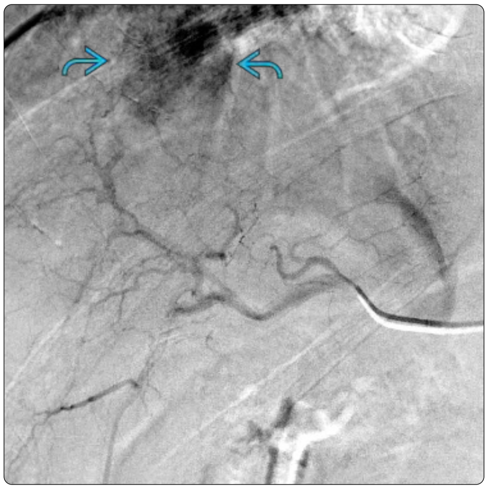


TACE as Bridge to Transplantation (Selective Proper Hepatic Artery DSA)

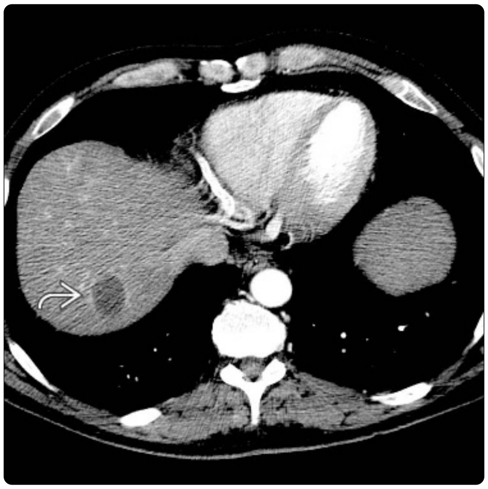


(Left) *Axial CECT in a patient with a history of cirrhosis shows a solitary, ill-defined, enhancing lesion ➡ in the hepatic dome, consistent with HCC. The patient was listed for transplantation and was referred for TACE as a bridging to transplant.* **(Right)** *A magnified view from a selective DSA of the proper hepatic artery ⇨ obtained during the TACE procedure shows an area of arterial enhancement → within hepatic segment VII, corresponding to the abnormal CECT findings.*

TACE as Bridge to Transplantation (Delayed Proper Hepatic Artery DSA)



TACE as Bridge to Transplantation (Posttreatment CECT Evaluation)



(Left) *Delayed parenchymal-phase image from the proper hepatic artery DSA shows the tumor blush ↪ to better advantage. After using a coaxial microcatheter to selectively catheterize the branch vessels supplying the tumor, treatment with DEB-TACE was performed.* **(Right)** *Axial CECT obtained 4 weeks after treatment with DEB-TACE shows a lack of contrast enhancement in the treated lesion ↪. This is the desired appearance following treatment and is consistent with a complete response to chemoembolization.*

KEY FACTS

TERMINOLOGY

- Treatment for nonoperable primary & secondary hepatic malignancies: Minimally invasive, catheter-directed therapy
- Injection of radioactive particles via hepatic artery resulting in selective internal irradiation of tumors
  - Yttrium-90 (^{90}Y): β-emitting radionuclide microspheres
  - Combines delivery of internal radiation to tumor, with embolization of feeding artery

PROCEDURE

- Treatment involves 2 separate procedures
  - Pre-SIRT evaluation: Embolization of hepaticoenteric arterial communications & ^{99}mTc-MAA injection via catheter placed in intended position for SIRT to calculate pulmonary shunting
  - ^{90}Y microsphere administration: Usually performed within 2 weeks of pre-SIRT evaluation
- 2 currently available ^{90}Y microspheres
  - ^{90}Y-doped resin (SIR-Spheres, Sirtex Medical; North Sydney, Australia)
  - ^{90}Y in glass matrix (TheraSphere, Nordion; Ottawa, Canada)
- Goal: Delivery of at least 120 Gy to tumor; less than 100 Gy appears to be ineffective
- Clean-up kit & trained clean-up crew must be available in case of spill

POST PROCEDURE

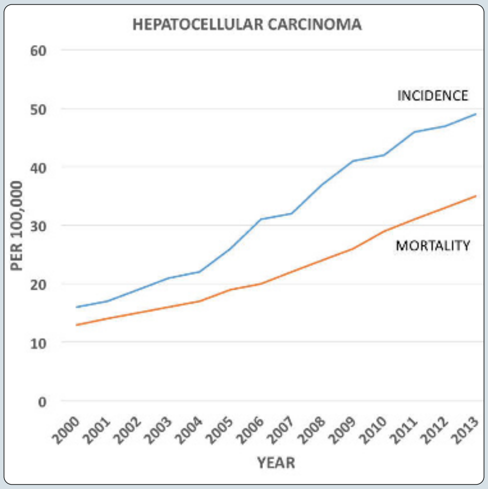
- MR & clinical evaluation after 6-8 weeks to assess response
- Further treatment (repeat ^{90}Y, TACE) if necessary

OUTCOMES

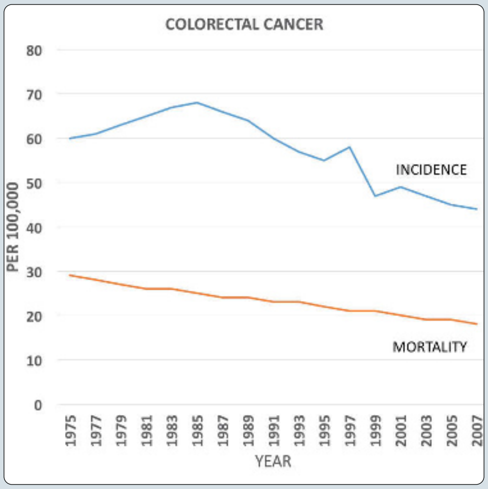
- Studies provide evidence of safety/efficacy of ^{90}Y treatment for primary & metastatic liver disease
- Improved survival in well-selected patients for colorectal metastatic disease
- Safety/efficacy of ^{90}Y therapy for HCC vs. other locoregional therapies needs further assessment

(Left) *There has been a steady increase in the incidence of hepatocellular carcinoma (HCC) mainly due to a concomitant increase in the incidence of hepatitis C.* **(Right)** *After peaking in the 80s, the incidence of liver metastatic colorectal cancer has gradually decreased.*

Epidemiology of Hepatocellular Carcinoma

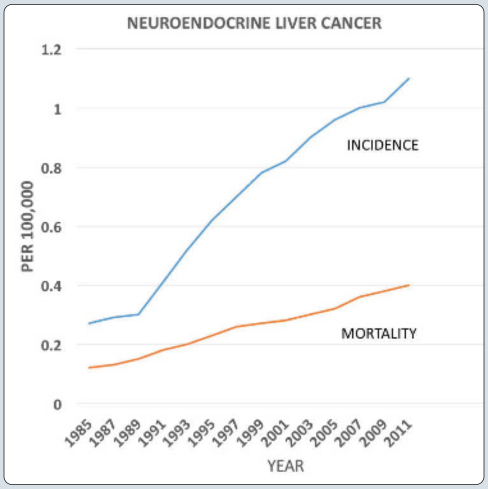


Epidemiology of Colorectal Cancer With Liver Metastases

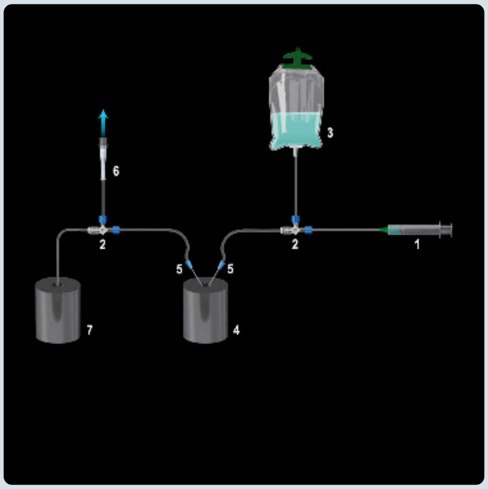


(Left) *The incidence of liver neuroendocrine cancer shows a gradual increase.* **(Right)** *The setup is designed to prevent spillage of radioactive material. Saline is withdrawn into the syringe (1) from a bag (3). A check valve (2) allows controlled pressure through a needle (5) & into the shielded vial containing the ^{90}Y (4). The pressure pushes the suspension through an output needle (5), then through a 2nd heck valve (2), & finally through the delivery catheter (6). Any suspension overflow is collected into another shielded vial (7).*

Epidemiology of Neuroendocrine Cancer With Liver Metastases



Schematic of Radioembolization Setup



Hepatic Radioembolization

TERMINOLOGY

Definitions

- **Selective internal radiotherapy (SIRT) or radioembolization or transarterial radioembolization (TARE)**
  - Anatomic & physiologic principles
    - Most of normal liver parenchyma is supplied via portal vein (70-80%)
    - Nearly all liver tumor supply is via the hepatic artery (90-100%)
    - Therefore, intraarterial treatment will preferentially target tumor & spare normal live parenchyma
  - Yttrium-90 (^{90}Y) is pure β emitter (energetic electrons)
    - Half-value layer is 2.5 mm; this means 50% of β particles are absorbed at every 2.5 mm of tissue penetration
    - At 10 mm (4 half-value layers), nearly all (93.75%) β particles have been absorbed
    - Small portion of β particle absorption (0.01%) is due to **bremsstrahlung** (breaking, decelerating), which results in γ radiation
    - γ radiation has much longer half-value layer; therefore, treated patients do emit some γ radiation
    - Half-life of ^{90}Y is 64 hours
  - Technical objective
    - Deliver ^{90}Y-loaded particles throughout arterial bed of tumor
    - Requires delivery of at least 120 Gy to tumor; less than 100 Gy appears to be ineffective
  - There are 2 commercially available ^{90}Y particles
    - Resin microspheres with median diameter 30 μm (SIR-Spheres, Sirtex Medical; North Sydney, Australia)
      - Lower radiation dose per particle (lower specific activity); therefore, significant embolization effect
    - Glass microsphere median diameter 25 μm (TheraSphere, MDS Nordion; Ottowa, Canada)
      - Higher radiation dose per particle (higher specific activity); therefore, little embolic effect
- **Pretreatment evaluation/shunt study**
  - Angiogram of hepatic arterial supply
    - (1) Define arterial supply to tumor & plan ^{90}Y delivery (split dose may be needed)
    - (2) Embolize (if needed) arterial branches that may be at risk for inadvertent nontarget embolization
      - Commonly gastroduodenal artery, falciform artery, left or right gastric artery
    - (3) Calculate shunt ratio
  - Shunt study
    - Injection of ^{99m}Tc-MAA (macroaggregated albumin) via catheter in anticipated position of ^{90}Y treatment
    - Followed by radionuclide lung-liver perfusion scan
      - Calculate percent activity in lung over total activity (lung & liver)
      - Shunt of < 15% is considered safe in patients with normal lung function
      - If COPD or other lung disease, consider lowering acceptable shunt fraction (< 10%)
- **^{90}Y microsphere administration**
  - Usually performed within 2 weeks of pretreatment study
  - If > 6 months from shunt study, consider repeating shunt study as tumor hemodynamics may have changed

PREPROCEDURE

Indications

- Unresectable hepatocellular carcinoma (HCC)
  - Only 10-15% of HCC patients are candidates for potentially curative therapy such as liver transplant, resection, or ablation
  - Low-level evidence suggests that SIRT may be noninferior to transarterial chemoembolization (TACE), which is current standard of care; however, level 1 evidence is lacking
  - Estimated new cases in USA (2014): 33,190
  - Estimated deaths from HCC in USA (2014): 19,550
    - 5th leading cause of death in men & 9th in women
  - Risk factors for HCC
    - Hepatitis B, hepatitis C, alcohol, nonalcoholic steatohepatitis, autoimmune factors, inherited factors, aflatoxin
- Unresectable hepatic metastatic disease
  - Colorectal cancer (CRC)
    - 60% CRC patients present with liver-dominant metastatic disease
    - Primary treatment of CRC metastases is resection if possible (plus neo- or adjuvant chemotherapy ± biologic agent)
    - If unresectable, standard of care is systemic chemotherapy ± biologic agent
    - SIRT can be used in combination with systemic chemotherapy or alone if systemic chemotherapy fails
  - Other secondary neoplasms treated: Carcinoid, breast, sarcomas, ocular melanoma, etc.
  - Cholangiocarcinoma (2nd most common primary liver cancer) has also been treated with ^{90}Y
- Transplant eligible HCC
  - Stop tumor progression while awaiting liver transplant
  - Maintain patients within Milan criteria
    - 1 tumor < 5 cm
    - Up to 3 tumors, each < 3 cm
    - No extrahepatic disease
    - No vascular invasion
  - Downstage HCC patients to within Milan criteria
  - Downstage patients with CRC metastases within resectable criteria

Contraindications

- Presence of nonliver-dominant metastases (significant extrahepatic disease)
- Poor baseline liver function
  - Liver parenchyma involvement of > 50%
  - Child-Pugh class C liver disease
    - More likely to die from underlying liver disease than tumor
  - Significant hepatic encephalopathy
  - Refractory ascites
  - Total bilirubin > 2 mg/dl, INR > 1.7, platelets < 50K
- Eastern Cooperative Oncology Group (ECOG) performance score > 2
  - ECOG performance status scale

- (0) Fully active; no restrictions
- (1) Physically strenuous activity restrictions; ambulatory & able to do light work
- (2) Ambulatory/self-care capable; unable to do any work activity; up/about > 50% of waking hours
- (3) Capable of only limited self-care; confined to bed or chair > 50% of waking hours
- (4) Completely disabled; cannot carry on any self-care; totally confined to bed or chair

- Excessive hepatopulmonary shunting following mapping study
  - Risk for radiation pneumonitis
    - Goal for < 30 Gy estimated pulmonary dose per treatment (healthy lungs)
    - Goal for < 50 Gy estimated cumulative lifetime pulmonary dose
- Portal vein thrombus, tumor or bland, is not contraindication to treatment

Preprocedure Imaging

- **Contrast-enhanced MR or CT**
  - Evaluation for HCC
    - US may be initial diagnostic imaging test, but cross-sectional baseline study is essential
      - Ideal to have triple-phase contrast imaging
      - Hypervascular mass with washout &/or AFP > 400 with mass in setting of cirrhosis diagnostic for HCC
    - Biopsy may rarely be needed for certain hepatic masses or to exclude metastatic disease
    - 3D liver & tumor volumes
      - Used to calculate amount of radioactivity to be delivered during treatment
      - Formulas available from 2 vendors
  - Can evaluate vessels on cross-sectional imaging
    - Arterial supply to tumor
      - Variant vascular anatomy
      - Branches at risk for nontarget embolization
    - Hepaticoenteric communications
    - Portal vein patency

Getting Started

- Things to check
  - Proper physician certification required
    - At least 1 physician on treatment team must be authorized user
    - Interventional radiologists receive formal didactic training in radiation biology, radiation physics, & radiation safety during residency in conjunction with certification by medical specialty board recognized by Nuclear Regulatory Commission (NRC)
  - Patient preparation
    - Proper indication (proper physician certification)
    - Consent
      - Discussion of risks should include radiation pneumonitis, liver decompensation, nontarget embolization, bone marrow depression in addition to standard embolization risks (hematoma, infection, etc.)
    - History & physical
    - Labs
      - Complete metabolic panel
      - Complete blood count
      - Coagulation profile
      - Liver function tests
      - α-fetoprotein
    - Patient allergies
- Medications
  - Intravenous conscious sedation
    - Fentanyl/midazolam typically used
  - Procedure premedications
    - Diphenhydramine: 50-mg IV
    - Dexamethasone: 10-mg IV
    - Ondansetron: 8-mg IV
    - Somatostatin analogs to mitigate possible neuroendocrine crisis
    - Routine use of prophylactic antibiotics has not been proven to be beneficial in low-risk patients; antibiotic premedication is therefore practice dependent
- Equipment list
  - Sheath
    - 5-Fr (or 6-Fr) vascular access sheath for common femoral access
    - 5-Fr (or 6-Fr) sheath for radial access
  - Catheters
    - Selective 5-Fr catheters
      - C1 or C2 Cobra
      - Simmons 1 or 2
      - SOS selective
    - Radial access catheters
      - 5-Fr to 6-Fr Glidesheath Slender (Terumo; Tokyo, Japan)
      - Jacky 5-Fr catheter (Terumo; Tokyo, Japan)
      - Sarah 5-Fr catheter (Terumo; Tokyo, Japan)
      - Glide JB1 catheter (Terumo; Tokyo, Japan)
    - Coaxial microcatheter: 0.025-0.027" inner lumen
      - Renegade (Boston Scientific; Natick, MA)
      - Progreat (Terumo; Tokyo, Japan)
      - Tracker (Target Therapeutics; San Jose, CA)
      - Maestro (Merit Medical; South Jordan, UT)
      - Direxion (Boston Scientific; Natick, MA)
  - Guidewires
    - 0.035" guidewire
    - 0.014-0.018" microwires
      - Transend (Boston Scientific; Natick, MA)
      - Glidewire GT (Terumo; Somerset, NJ)
      - Fathom (Boston Scientific; Natick, MA)
  - Embolization coils
    - 0.035" or 0.018" pushable or detachable embolization coils
      - To embolize arterial branches at risk for nontarget embolization prior to ^{90}Y delivery

Radioactive Microspheres

- **SIR-Spheres** (Sirtex Medical; North Sydney, Australia): ^{90}Y-doped resin
  - Current FDA approval: Treatment of unresectable hepatic metastases from 1° CRC with adjuvant intrahepatic artery chemotherapy of floxuridine
    - Biocompatible; nonbiodegradable microsphere
      - Sphere diameter of 20-60 μm
      - Assumed activity per sphere: 50 Bq

    - Shelf life: 24 hours after calibration
  - Supplied in vial containing 3 GBq ^{90}Y in 5 mL water
    - Vial shipped in 6.4-mm-thick lead pot
  - Administration components
    - SIR-Spheres administration set
    - Perspex shield
    - Dose vial
    - Inlet & outlet tubing
    - Injection syringe for sterile water, contrast
- **TheraSphere** (MDS Nordion; Ottawa, Canada): ^{90}Y in glass matrix
  - Approved in USA under Humanitarian Device Exemption (HDE); FDA requires Institutional Review Board (IRB) oversight of use at each institution
  - Current FDA approval: Radiation treatment or neoadjuvant to surgery/transplantation for unresectable HCC
    - Nonbiodegradable microsphere
      - Mean sphere diameter of 25 μm
      - Contains ^{90}Y in glass matrix; yttrium unable to leak out
      - Assumed activity per sphere: 2,500 Bq
    - Supplied in 0.6 mL of sterile water contained in 1.0-mL vial secured in clear acrylic vial shield
      - Available in 6 dose sizes
      - 1-mg aggregate weight of 22,000–73,000 spheres
    - Shelf life: 12 days after calibration
  - Administration components
    - TheraSphere administration set
    - Lucite shield
    - Empty vial
    - Inlet & outlet tubing
    - Interlocking units: Positioning needle guide, priming needle guide
    - Injection syringe with saline

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Supine
    - Common femoral artery access
    - Radial access
      - When femoral artery access is not an option (dense calcification, etc.)
      - Faster recovery especially since patient may ambulate immediately post procedure

Equipment Preparation

- Cover fluoroscopy pedal/controls to protect against spill
- Cover procedure room floor with absorbent drapes
  - Confines any potential contamination
- Anyone leaving room during procedure is scanned for radioactive contamination
- Clean-up kit & trained clean-up crew must be available in case of spill

Procedure Steps

- **Initial angiography & shunt study**
  - Sterilely prepare/drape intended access site
  - Obtain arterial access, place sheath
  - Perform aortogram; compare prior cross-sectional images
    - Identify normal/potential variant mesenteric branches
  - Perform superior mesenteric angiogram
    - Evaluate portal vein patency
    - Evaluate variant anatomy
  - Perform celiac artery angiogram
    - Define hepatic arterial anatomy
    - Evaluate potential for nontarget vessel embolization
  - Perform common/proper hepatic arteriogram
    - Evaluate for tumor arterial supply
      - Perform right & left hepatic arteriograms
      - Evaluate for hepaticoenteric communications
    - Consider C-arm CT
      - C-arm CT gives 3D vascular anatomic display & perfused territory, plus increased ability to identify nontarget tissue enhancement/involvement
      - Dilute contrast 50% with saline
      - Proper hepatic artery: Contrast injection of 3 mL/sec, 36 mL total, 8-second x-ray delay
      - Right hepatic artery: Contrast injection of 2 mL/sec, 24 mL total, 8-second x-ray delay
      - Left hepatic artery: Contrast injection of 1 mL/sec, 12 mL total, 8-second x-ray delay
  - Prophylactically coil embolize vessels that may be at risk for nontarget radioembolization
    - Gastroduodenal artery
    - Right gastric artery
      - Very small branch; arises from proper hepatic artery in 53% of patients
    - Supraduodenal artery
      - Present in 93% of patients; highly variable origin
    - Falciform artery
      - Originates from left or middle hepatic artery
      - Oblique caudal course to anterior abdominal wall
    - Accessory or left phrenic artery
    - Intrahepatic arterial gastroesophageal branches, usually from distal left hepatic artery
    - Left gastric artery
  - Infuse ^{99m}Tc-MAA particles via catheter placed in expected treatment branch
  - Follow with whole-body γ camera imaging
    - Predicts distribution of ^{90}Y microspheres
    - Assesses hepatic/possible extrahepatic deposition
    - Assesses magnitude of pulmonary shunting
      - Shunt ratio calculation: Lung counts vs. total counts
      - Projected lung dose should be below maximum dose of 30 Gy to 1-kg lung mass
      - For 10-15% shunting, decrease dose by 20-40%
      - For 15-20% shunting, decrease dose by 40-60%
      - Should avoid treatment if > 20% shunt value or > 16.2 mCi (600 MBq) delivered to lung
- **^{90}Y microsphere administration**
  - Should perform within 2 weeks of initial mesenteric mapping & ^{99m}Tc-MAA scan
  - Repeat diagnostic DSA prior to treatment
    - Celiac & proper hepatic arteriograms
      - Prophylactically coil embolize any newly identified extrahepatic communications if not previously done

  - Assemble ^{90}Y microsphere delivery apparatus after delivery catheter in proper position
    - Follow manufacturer-specific protocol
  - Can deliver lobar, segmental, or subsegmental ^{90}Y microsphere dose; whole-liver dose on occasion
  - Use enough pressure to maintain spheres in suspension when injecting ^{90}Y microspheres
    - Inject in nonforceful, pulsatile manner
      - Avoids/minimizes potential for reflux
  - Infusion complete if entire dose delivered or stasis
    - Do not continue injection after stasis; increases risk of reflux/nontarget radiation
  - Verify dose delivery by radiation monitoring of administration set/catheter
  - Radiation survey of room & personnel after procedure
    - Exclude any radioactive contamination
  - Collect all contaminated items
    - Dispose of as radiation waste

Alternative Procedures/Therapies

- Radiologic
  - TACE
    - Standard of care for unresectable HCC is TACE
  - Percutaneous tumor ablation
    - e.g., radiofrequency/microwave/cryoablation
    - If tumor (HCC or CRC metastases is amenable to ablation), then ablation is standard of care because it is potentially curative
- Surgical
  - Surgical resection (if candidate)
  - Liver transplant for HCC (if candidate)
- Other
  - Continue concurrent recommended oncologic treatments
    - Often no need to hold antiangiogenic medications during ^{90}Y treatment & planning
    - Follow oncology recommendations regarding chemotherapeutics
    - Data is currently lacking

POST PROCEDURE

Things to Do

- Monitor patient for 4-6 hours after procedure
  - Postprocedure & sedation monitoring
- Patient is usually discharged same day
  - Patient's tissues provide sufficient attenuation of β emissions; can be released immediately
    - Trace amounts of radioactivity in patient's urine
      - Double toilet flushing recommended
      - Keep toilet lid closed for at least 24 hours
  - May admit overnight if necessary
    - No restrictions imposed on routine nursing care
- Provide symptomatic control of postembolization syndrome if present (usually minimal)
  - Provide pain control
  - Administer antiemetics as necessary
    - Ondansetron: 4-8 mg
    - Prochlorperazine: 5-10 mg
  - Administer antipyretics as necessary
    - Ibuprofen: 200-400 mg
- Administer proton pump inhibitor medication
  - Pantoprazole sodium: 40 mg (minimizes risk of gastrointestinal irritation)
    - Start at time of pretreatment angiography
    - Continue for at least 4 weeks after
- Monitor arterial access site
  - Evaluate for bleeding/hematoma/pulse loss
- No post-SIRT antibiotic treatment is necessary in low-risk patients (no history of embolization-related infection, compromised sphincter of Oddi, biliary instrumentation, etc.)

Postprocedure Imaging/Follow-Up

- Obtain imaging 6-8 weeks following treatment
  - Contrast-enhanced MR or CT
    - Modified Response Evaluation Criteria In Solid Tumors (mRECIST) criteria
      - Complete response: Disappearance of any arterial enhancement in all target lesions
      - Partial response: At least 30% decrease in sum of diameters of viable target lesions (reference baseline sum of diameters of target lesions)
      - Stable disease: Any cases not qualifying as partial response or progressive disease
      - Progressive disease: Increase at least 20% increase in sum of diameters of viable (enhancing) target lesions (reference smallest sum of diameters of viable target lesions recorded since treatment started)
    - European Association for the Study of the Liver (EASL) criteria
      - Complete response: No arterial enhancement of treated lesions present
      - Partial response: Over 50% decrease in arterial enhancing area (sum longest diameters multiplied by sum perpendicular diameters)
      - Stable disease: Any case not qualifying as either partial response or progressive disease
      - Progressive disease: Over 25% increase in size-enhancing areas or new lesion(s)
    - May see effects on other organs
      - Thickening of duodenal/gastric/gallbladder wall
  - PET images can show decreased metabolic activity
    - Indicates treatment response
- Repeat clinical assessment
  - Liver function tests/tumor markers
  - ECOG performance status
  - Evaluate for hematologic or renal toxicity
  - Recalculate Child-Pugh score
- Further treatment can be planned if necessary
  - Repeat ^{90}Y treatment
  - May consider TACE or ablation treatment depending on response to ^{90}Y

OUTCOMES

Complications

- Most feared complication(s)
  - Nontarget embolization of ^{90}Y microspheres
    - Can cause gastrointestinal ulceration/necrosis

            - Published incidence: 0-29%; should be < 2%
            - Manifests as persistent pain/nausea/vomiting/bleeding; may be at risk for bowel perforation
            - Should have low threshold for endoscopy
        - Can cause radiation cholecystitis (rare)
            - Usually inconsequential, minority of patients require cholecystectomy
            - Avoid with infusion by administering ^{90}Y distal to cystic artery
    - Progressive pulmonary insufficiency
        - Secondary to radiation pneumonitis
            - Prevent by avoiding ^{90}Y therapy in any patient with marked hepatopulmonary shunting
- Hepatic failure/hepatic infarction
    - Radiation-induced liver disease (rare)
        - Various degrees of hepatic decompensation
            - Treat with high doses of corticosteroids; attempt to decrease intrahepatic inflammation
        - Manifests clinically by anicteric ascites
        - Typically occurs 4-8 weeks post treatment
- Postembolization syndrome characterized by pain, fatigue, fever, vomiting, & anorexia
- Pancreatitis
- Biliary injury
    - Biliary stricture/biloma/biliary necrosis
- Decreased platelet or white blood cell counts
- Arterial access site complications
    - e.g., hematoma, pseudoaneurysm
- Spill: Spill kit & clean-up crew should be available

Expected Outcomes

- Improved survival in well-selected patients
    - HCC
        - Intermediate stage unresectable HCC
            - Median natural history survival: 12 months
            - Median survival post intraarterial liver treatment: 20 months
    - Colorectal metastatic disease in liver
        - SIRFLOX: ^{90}Y + mFOLFOX6 vs. mFOLFOX
            - 31% reduction in risk of progression in liver disease
            - Increase in progression-free survival in liver from 12.6 to 20.5 months

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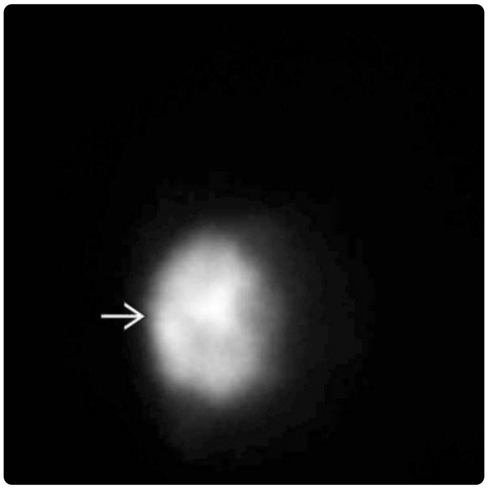
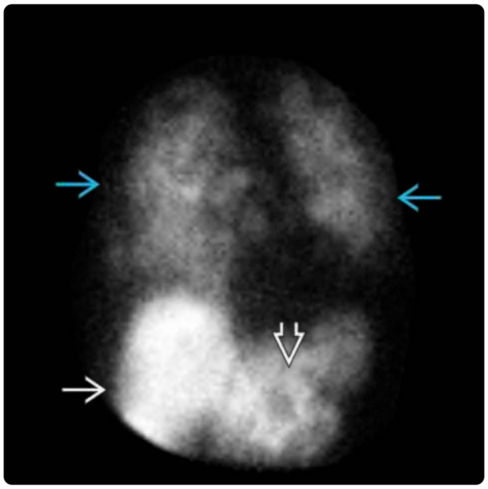
(Left) *Post ^{99m}Tc-MAA SPECT image is shown. Activity is noted only in the liver* ➡. *Shunt was calculated at 2%. ^{90}Y radioembolization can proceed without risk for radiation pneumonitis.* **(Right)** *Post intraarterial hepatic infusion ^{99m}Tc-MAA SPECT image is shown. Activity is noted in the liver* ➡ *& lungs* →. *Shunt was calculated at 22%, which precludes radioembolization. Note extrahepatic activity in upper viscera* ➡. *This indicated aberrant vascular anatomy, arterioportal shunting, or overzealous injection.*

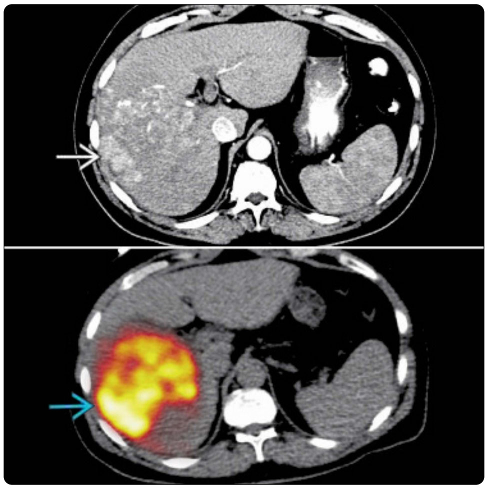


Normal Shunt Study

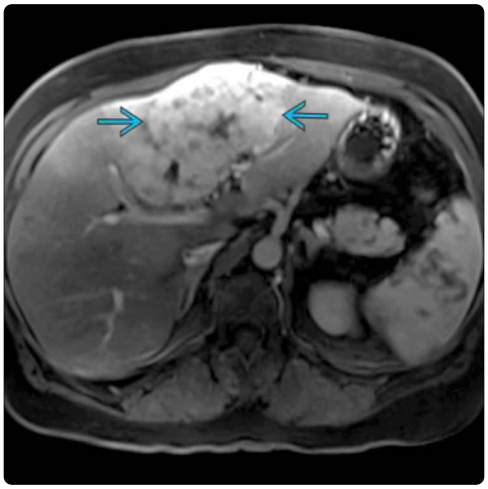


Abnormal Shunt Study

(Left) *A large infiltrative, irregularly enhancing HCC* ➡ *is noted in hepatic segments V & VI (top). A post-^{90}Y PET/CT (bottom) shows excellent correlation between the enhancing portions of the tumor & ^{90}Y deposition* →. **(Right)** *In a different 57-year-old woman with cholangiocarcinoma, the left-sided, solid enhancing tumor* → *failed to respond to transarterial chemoembolization (TACE). Multidisciplinary board recommended selective internal radiotherapy (SIRT).*

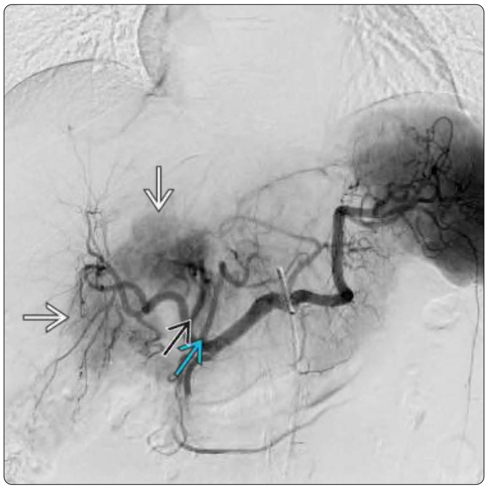


^{90}Y Distribution After Treatment

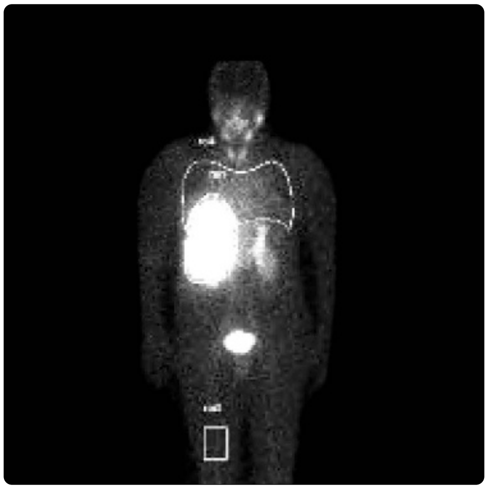


Cholangiocarcinoma (MR Post-TACE)

(Left) *Planning celiac arteriogram shows the hypervascular mass* ➡ *supplied by 2 vessels. One supplying segments II & III* → *& one supplying segment IVa & IVb* ⇒. **(Right)** *Shunt study evaluation calculated the lung:shunt ratio to be 4.5%. When lung shunting is < 10%, no reduction of the planned ^{90}Y dose is necessary.*

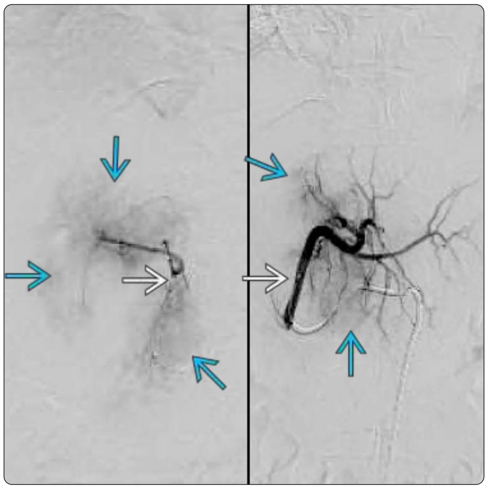


Cholangiocarcinoma (Pre-SIRT Planning Arteriogram)

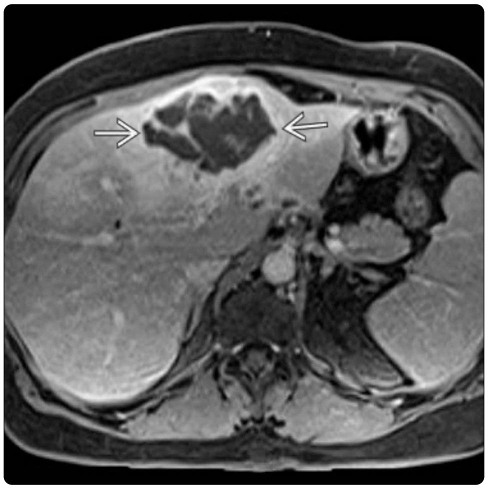


Cholangiocarcinoma (Pre-SIRT Shunt Study)

Cholangiocarcinoma (Delivery of Split ^{90}Y Dose)

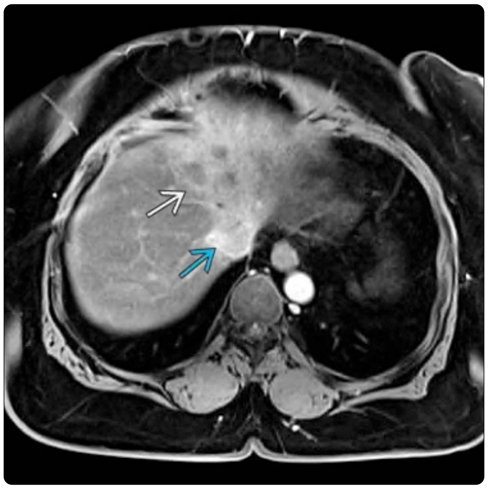


Cholangiocarcinoma (Post-SIRT Follow-Up MR)

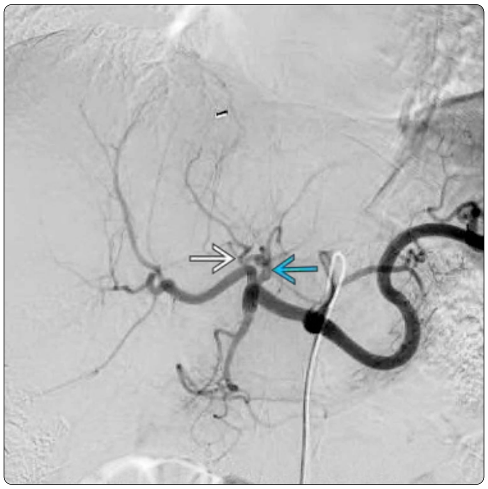


(Left) *Because the target lesion was supplied by 2 vessels, the total dose was split. Segments IVa & IVb (left) & segments II & III (right) were subselected with a microcatheter* ➡ *& treated individually. The tumor blush* ⇨ *is seen in each case.* **(Right)** *Three-month follow-up MR shows a sightly diminished in size, but mostly necrotic, tumor* ➡*. Note that the use of RECIST or WHO response criteria would underestimate response. Proper response criteria are mRECIST or EASL.*

Unresectable Primary Hepatic Tumor (Pre-SIRT MR)

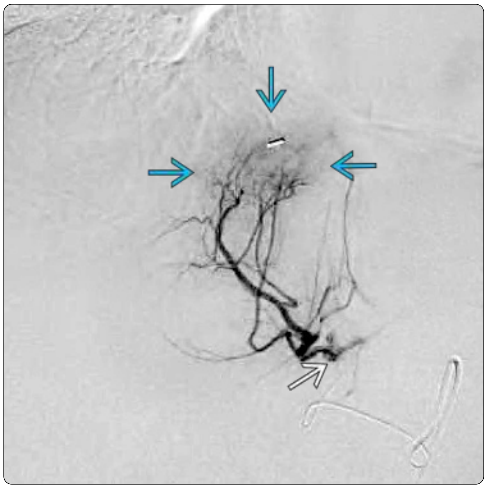


Unresectable Primary Hepatic Tumor (Pre-SIRT Planning Arteriogram)

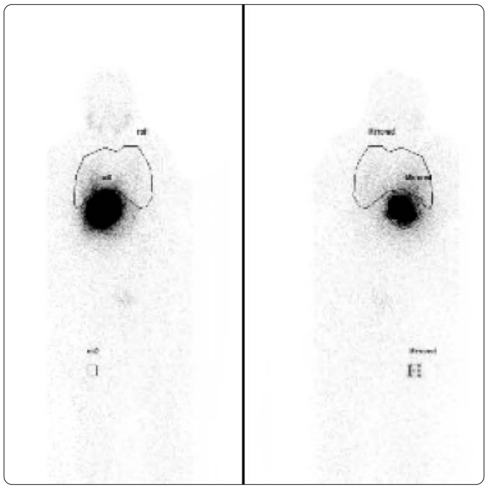


(Left) *MR of another case of cholangiocarcinoma in a 63-year-old man reveals an infiltrative hypervascular mass in segment IVa* ➡*. The mass extends to the intrahepatic IVC* ⇨*, making it unresectable.* **(Right)** *The planning celiac arteriogram reveals that the medial & lateral left hepatic lobe segments are again supplied individually. A medial left hepatic artery* ➡ *supplies segments IVa & IVb, while a lateral hepatic artery* ⇨ *supplies segments II & III.*

Unresectable Primary Hepatic Tumor (Pre-SIRT Selective Arteriogram)

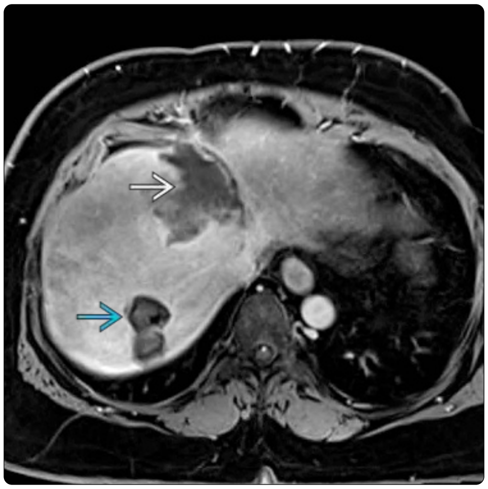


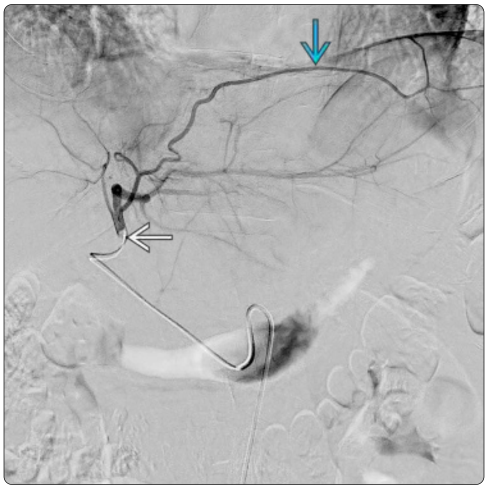
Unresectable Primary Hepatic Tumor (Pre-SIRT Shunt Study)



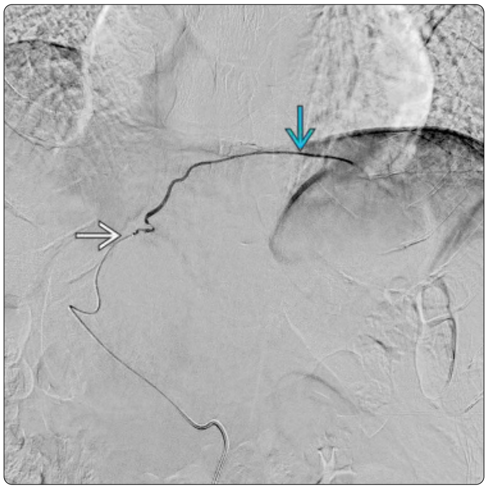
(Left) *A microcatheter was advanced into the medial left hepatic artery. A selective segment IV arteriogram* ➡ *shows the hypervascular tumor* ⇨ *to better advantage. There are no collateral vessels requiring embolization (e.g., right gastric artery) prior to ^{90}Y delivery.* **(Right)** *A shunt study estimated the lung shunt percent at 8.5. No abnormal foci of radio-tracer uptake are present outside of the liver.*

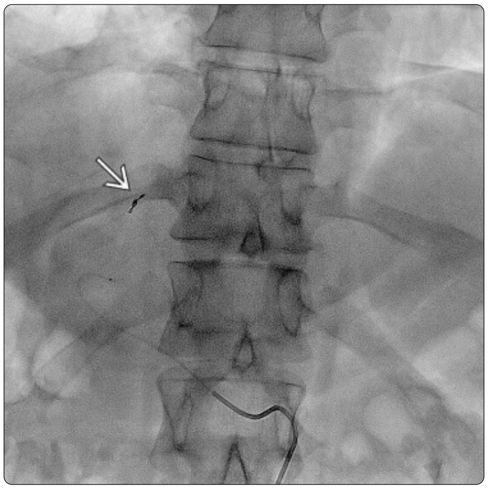
(Left) *SIRT was performed in both hepatic lobes. Subsequently, a 5-month follow-up MR shows near complete devascularization of the segment IVa lesion* ➡ *as well as 2 smaller lesions in the right lobe* ⇨. **(Right)** *A 72-year-old man with unresectable HCC underwent pre-SIRT planning. A selective arteriogram with a microcatheter in the left hepatic artery* ➡ *noted aberrant vascular anatomy. The left phrenic artery* ⇨ *originated from the left hepatic artery.*


Unresectable Primary Hepatic Tumor (Post-SIRT Follow-Up MR)

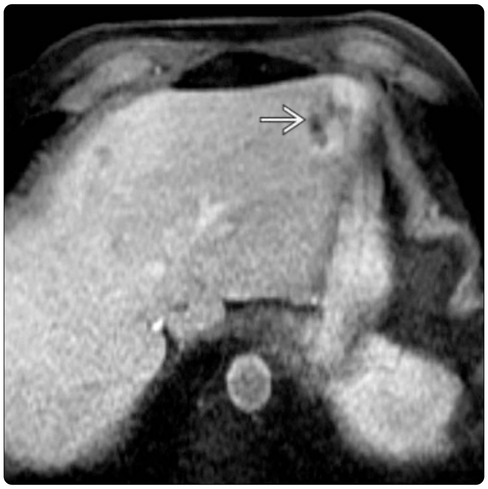

Aberrant Phrenic Artery (Pre-SIRT Planning Arteriogram)

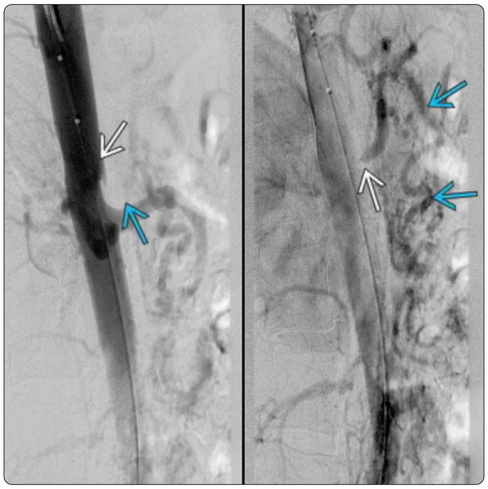
(Left) *To avoid nontarget phrenic artery radioembolization, this replaced vessel must be embolized prior to SIRT. The microcatheter* ➡ *is advanced into the aberrant phrenic artery* ⇨. **(Right)** *Coil* ➡ *embolization of the aberrant left phrenic artery eliminates the risk of nontarget radioembolization. All nontarget vessels that are at risk for injury during SIRT must be embolized if possible.*

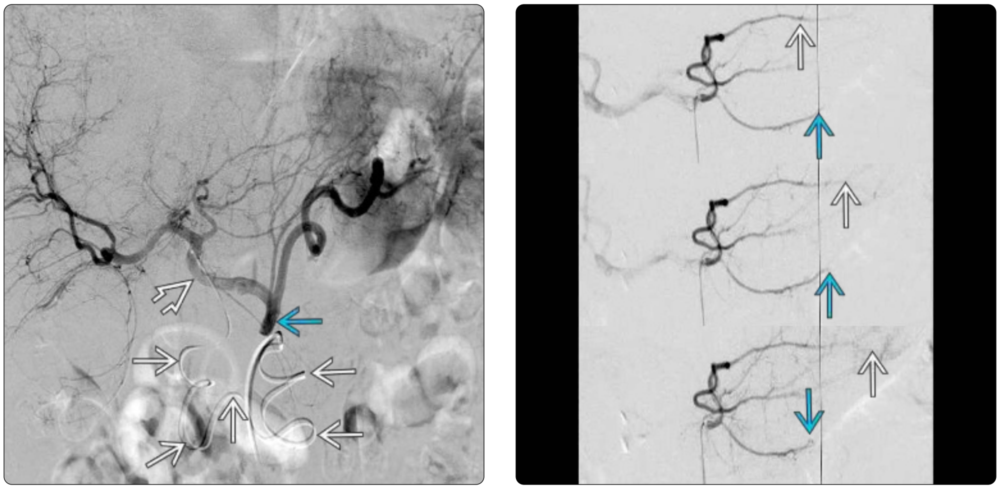

Aberrant Phrenic Artery (Catheterization of Aberrant Artery)


Aberrant Phrenic Artery (Post Embolization of Aberrant Artery)

(Left) *A 61-year-old man with left liver colorectal metastasis was presented at multidisciplinary board. SIRT was recommended since the patient was a poor anesthesia candidate. A single, hypervascular lesion* ➡ *is noted in segment II of the liver.* **(Right)** *Early (left) & late (right) arterial phase of a lateral abdominal aortogram shows an occluded celiac axis* ➡*. The celiac artery is reconstituted by retrograde flow from the SMA* ⇨*. Catheter advancement to the liver through the celiac artery origin is not possible.*


Celiac Artery Occlusion (Pre-SIRT MR)

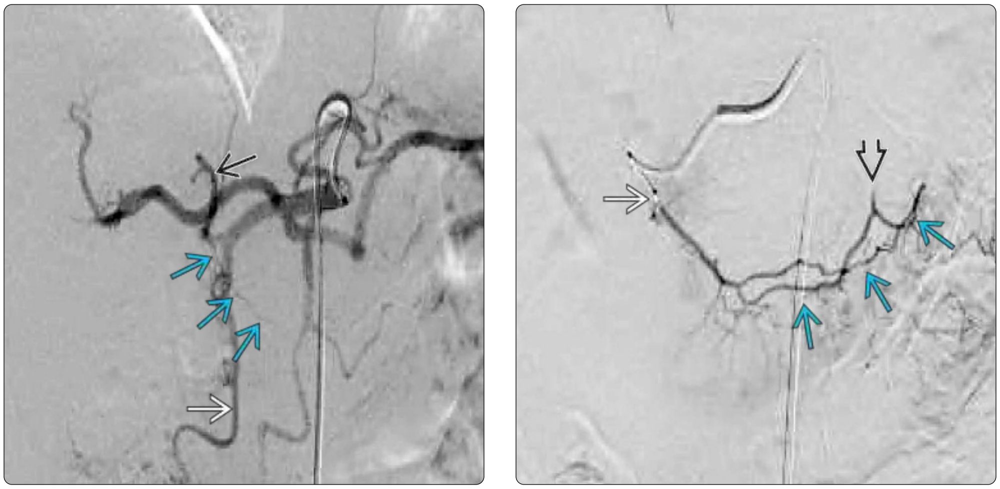

Celiac Artery Occlusion (Lateral Aortogram)



Celiac Artery Occlusion (Catheter Advancement via Collateral Path)

Celiac Artery Occlusion (Left Hepatic With Aberrant Right Gastric Artery)

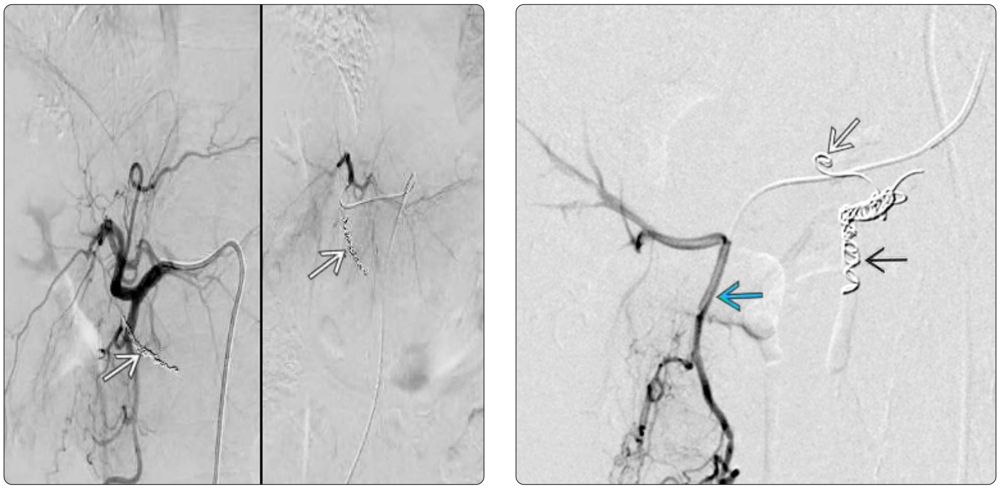
(Left) *A microcatheter ➡ advanced via a very tortuous path from the SMA, through the pancreaticoduodenal arcade, to the proper hepatic artery ➡, where contrast opacified the celiac axis ➔ & its branches.* **(Right)** *In successive (top to bottom) left hepatic arteriograms, left hepatic artery branches ➡ are seen successively penetrating more distally. Conversely, the lower branch ➔ vacillates distally-proximally, raising concerns as the right gastric artery. This was missed, resulting in gastric perforation & patient mortality.*



Right Gastric Artery (Angiographic Localization)

Right Gastric Artery (Selective Catheterization)

(Left) *Celiac arteriogram shows early bifurcation of the common hepatic artery with the left hepatic artery ⇨ communicating with the GDA ➡ & right gastric artery ➔ in this 58-year-old patient presenting with unresectable multifocal colorectal liver metastatic disease. Because SIRT was planned in the left lobe, embolization of this vessel was necessary.* **(Right)** *A selective arteriogram of the vessel via a microcatheter ➡ confirms supply to the lesser curvature of the stomach ➔. Competing flow from the left gastric artery is noted ⇨.*



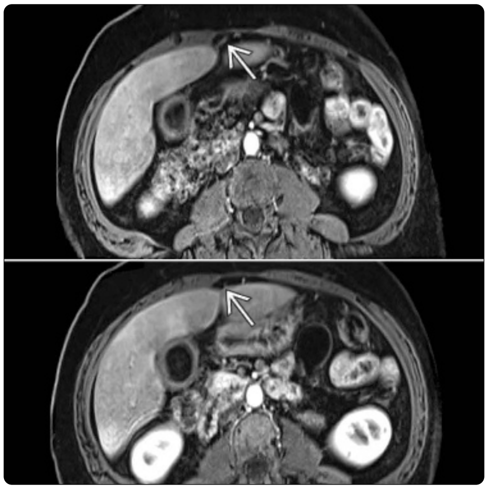
Right Gastric Artery (Coil Embolization)

Cystic Artery Embolization

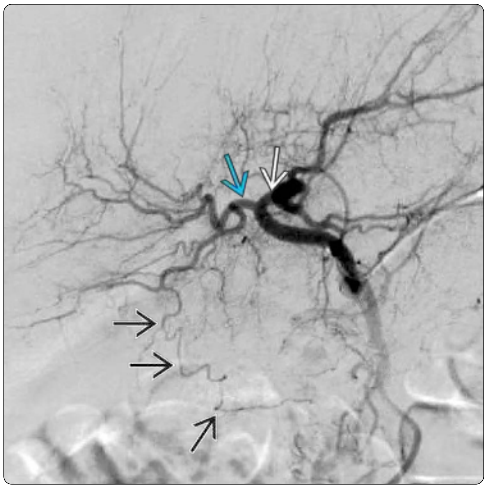
(Left) *Selective common left hepatic-GDA (left) & superselective left hepatic arteriograms (right) after coil embolization show occlusion of the right gastric artery ➡. Nontarget radioembolization of the right gastric artery can cause significant morbidity, even mortality.* **(Right)** *During the planning arteriogram, the right gastric artery ➡ & GDA ⇨ were embolized to prevent ^{90}Y reflux. While not necessary, this large cystic artery ➔ was also embolized because of its size.*

(Left) *Review of the baseline MR shows the falciform artery* ➡ *emerging between the medial & lateral liver lobes. Careful scrutiny of the arterial phase MR or CT can reveal aberrant anatomy & guide the planning arteriogram.* **(Right)** *In another case, a left hepatic arteriogram displays the left lateral* ➡ *& left medial segment* ⇨ *branches. Off the latter, the tortuous, thin falciform artery* → *is noted. Inadvertent radioembolization of this vessel could result in anterior abdominal pain &/or skin/fat necrosis.*

Falciform Artery

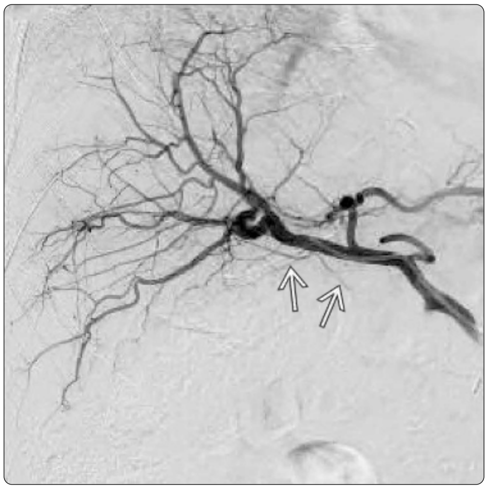


Falciform Artery

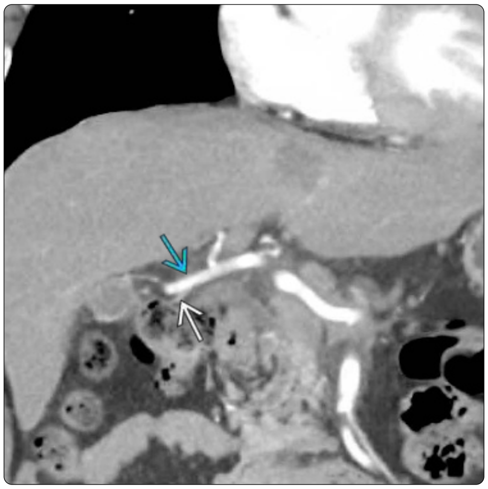


(Left) *A proper hepatic arteriogram in a 51-year-old man with colorectal metastasis shows a small vessel* ➡ *bifurcating inferior to the main right hepatic artery with a suspected extrahepatic course.* **(Right)** *Review of an arterial phase CT revealed a previously unnoticed supraduodenal branch* ➡ *off the right hepatic artery* ⇨*. Inadvertent radioembolization could result in duodenal ulceration or even perforation. Distal treatment or coil embolization of this branch will mitigate this risk.*

Supraduodenal Artery (Pre-SIRT Planning Arteriogram)

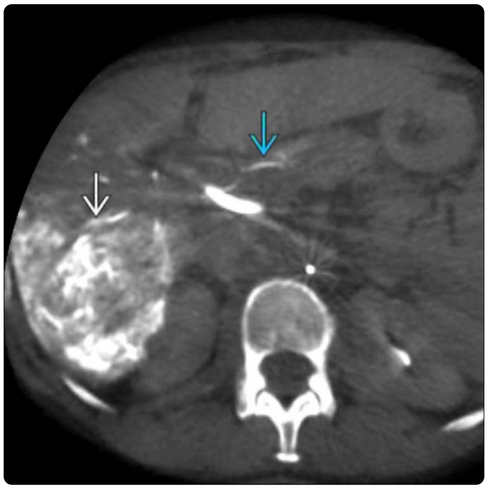


Supraduodenal Artery (Coronal CECT)

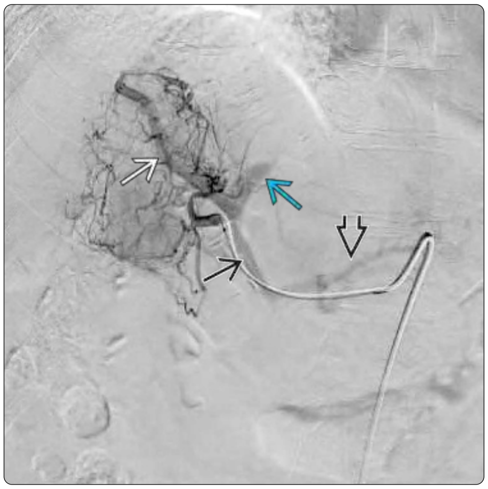


(Left) *Arterial phase cone-beam CT in an 83-year-old man with HCC highlights the lesion in the right lobe* ➡*, & a small aberrant vessel* ⇨ *supplying the anterior pancreas.* **(Right)** *A right hepatic arteriogram in a 61-year-old woman with HCC shows premature opacification of the right* ➡*, left* ⇨*, & main* → *portal veins & splenic vein* ⇒*. SIRT embolization risks include (1) ineffective treatment due to distribution of the dose in the entire liver & (2) nontarget injury to the stomach, bowel, or pancreas.*

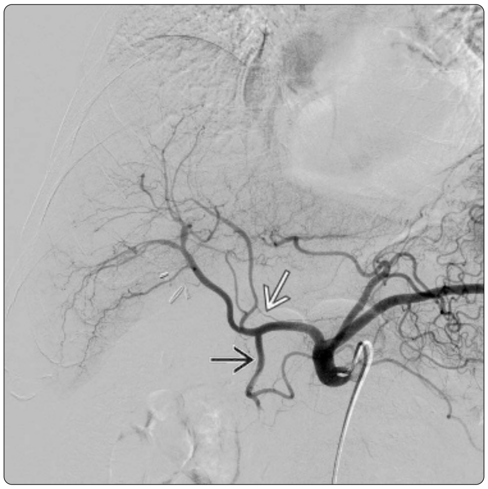
Importance of Cone-Beam CT



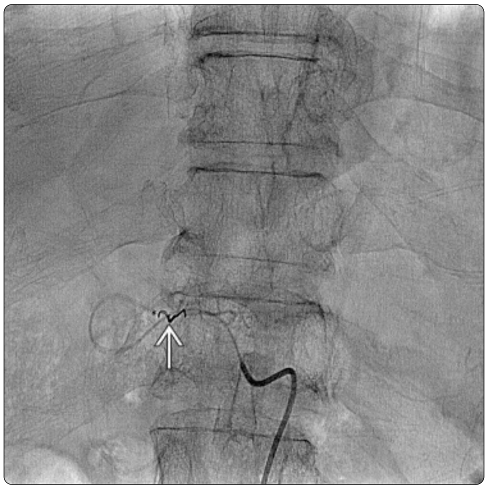
Arterioportal Shunting



Typical Pre-SIRT Celiac Arteriogram (GDA & Right Gastric Visualization)

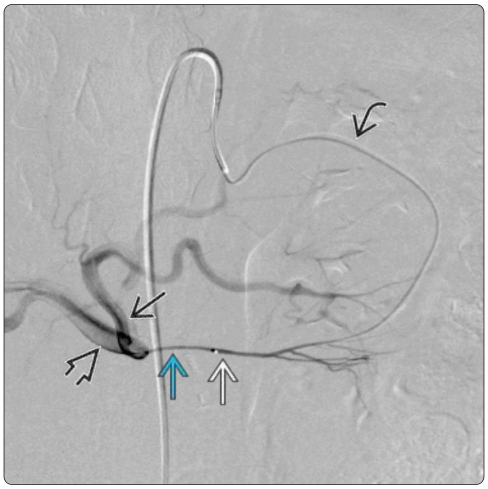


Typical Pre-SIRT Celiac Arteriogram (Coil Deployed Into Right Gastric Artery)

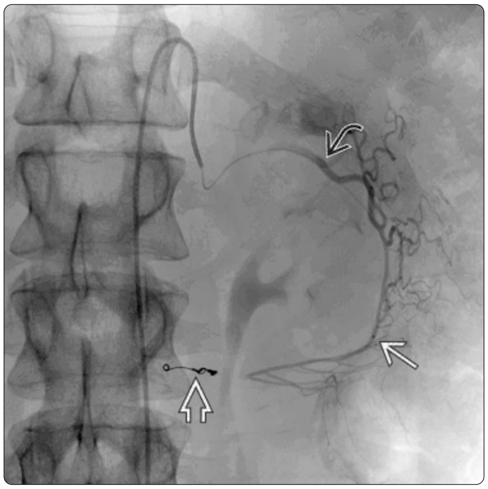


(Left) *A planning angiogram in a 52-year-old with metastatic colorectal cancer to the liver illustrates a right gastric artery ➔ arising from the left hepatic artery. In addition, the GDA → is in close proximity to the left hepatic artery origin. A left SIRT was planned, necessitating preemptive embolization of both vessels.* **(Right)** *In this case, the microcatheter was advanced through the left hepatic artery into the right gastric artery. Embolization of the right gastric artery was performed using a pushable coil ⇨.*

Right Gastric Embolization via Left Gastric Artery (Arteriogram)

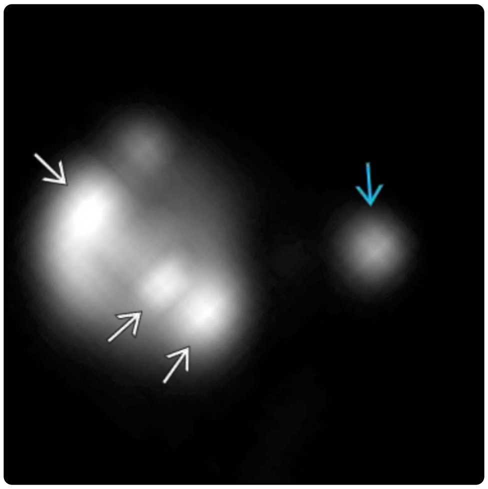


Right Gastric Embolization via Left Gastric Artery (Post Coil Embolization)

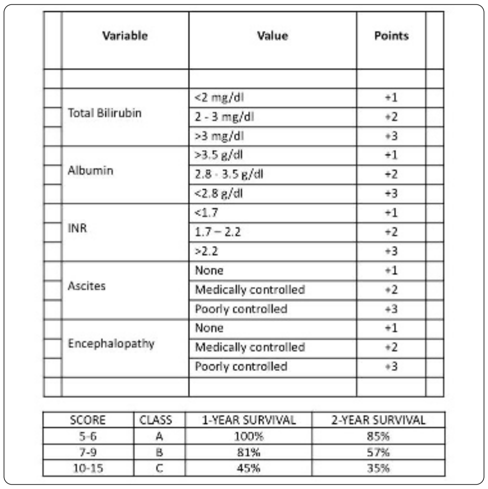


(Left) *During a planning arteriogram, the right gastric artery → was seen arising off a bend at the bifurcation of the left hepatic → & right hepatic ⇨ arteries. The microcatheter ➔ would not engage the right hepatic artery via the proper hepatic artery & was therefore advanced through the left hepatic artery ↪.* **(Right)** *After coils ⇨ occluded the right gastric artery origin, the microcatheter ➔ was withdrawn & contrast injected outlining the course of the left gastric artery ↪.*

Extrahepatic Radiotracer (Post Shunt Study SPECT)



Child-Pugh Staging System



Variable	Value	Points
Total Bilirubin	<2 mg/dl	+1
	2 - 3 mg/dl	+2
	>3 mg/dl	+3
Albumin	>3.5 g/dl	+1
	2.8 - 3.5 g/dl	+2
	<2.8 g/dl	+3
INR	<1.7	+1
	1.7 – 2.2	+2
	>2.2	+3
Ascites	None	+1
	Medically controlled	+2
	Poorly controlled	+3
Encephalopathy	None	+1
	Medically controlled	+2
	Poorly controlled	+3

SCORE	CLASS	1-YEAR SURVIVAL	2-YEAR SURVIVAL
5-6	A	100%	85%
7-9	B	81%	57%
10-15	C	45%	35%

(Left) *The shunt study shows multifocal intrahepatic activity ➔ in a patient with known colorectal metastatic disease. An extrahepatic focus of activity is also seen →. Review of the planning angiogram showed a supraduodenal artery, which was missed. Extrahepatic Tc-99 activity should prompt further investigation to prevent nontarget embolization.* **(Right)** *The Child-Pugh system provides survival prediction based on the patient's stage of cirrhosis. It does not, however, include the contribution of HCC.*

KEY FACTS

PREPROCEDURE

- **Indications for ablation**
  - Renal cell carcinoma; ideal lesion ≤ 3 cm; acceptable results in tumors < 4 cm
  - Risk of incomplete ablation rises with lesion size
- **Indications for embolization**
  - Angiomyolipoma (AML) > 4 cm; nonruptured aneurysms > 5 mm
- Review prior imaging
  - Thermal ablation injury risk if tumor near collecting system; consider pyeloperfusion
  - Determine vascularity of AML before treating

PROCEDURE

- **Ablation**
  - CT guidance used for most renal ablations
    - Goal: Ablation zone completely encompasses tumor plus 0.5-1.0-cm margin
- **Embolization**
  - Perform as selectively as possible
    - Devascularize AML; preserve normal renal tissue

POST PROCEDURE

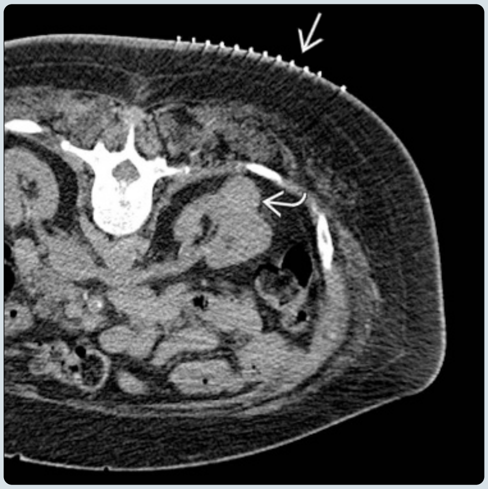
- **Ablation**
  - ≥ 90% complete necrosis in mass ≤ 4 cm
    - CT/MR nonenhancement correlates with necrosis
- **AML embolization**
  - Success rate of 90-100%
    - Tumor does not disappear; decreases by 40-66%
- Residual disease or local progression manifested by
  - Peripheral enhancing nodule(s) or crescent
  - Morphologic changes/growth on serial scans

OUTCOMES

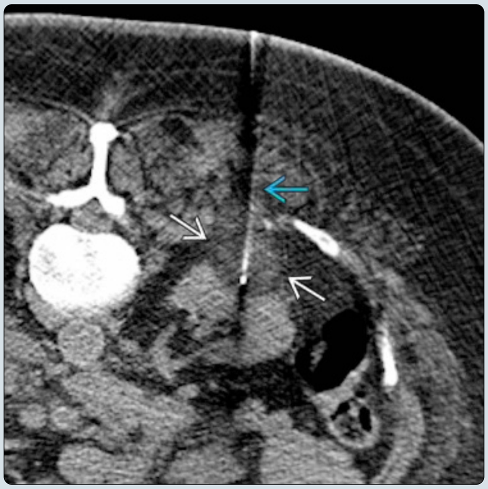
- **Most feared complications**
  - **Ablation**: Ureteral stricture/bowel perforation
  - **Embolization**: Nontarget embolization

(Left) *Intraprocedural NECT demonstrates the marker grid on the skin* ➡ *in preparation of probe placement. The exophytic renal mass* ↪ *is noted at the posterior aspect of the kidney.* **(Right)** *Intraprocedural NECT demonstrates the cryoprobe* ⇨ *within the tumor during the freeze cycle of the ablation. The margins of the ice ball are visualized* ➡.

Cryoablation (Localizing NECT)

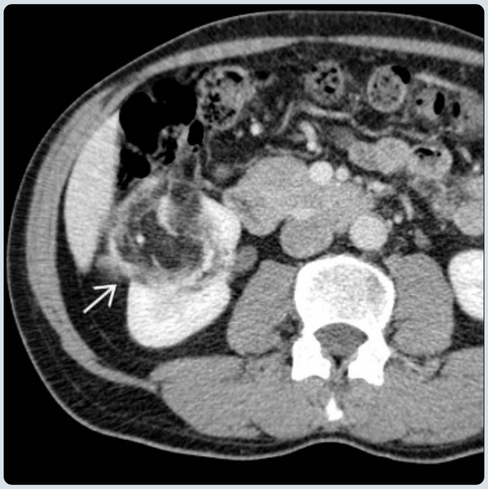


Cryoablation (Freeze Cycle)

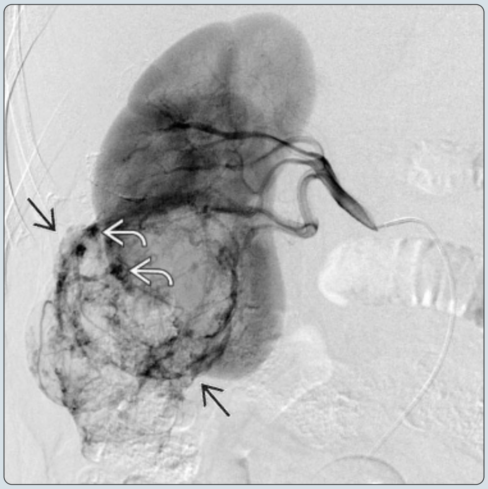


(Left) *Axial CECT demonstrates a large, mixed-attenuation mass involving the right kidney, consistent with an angiomyolipoma (AML)* ➡. **(Right)** *Selective right renal arteriogram in the same patient demonstrates a large, hypervascular lower pole mass* ⇨ *with focal pseudoaneurysms* ↪. *The large size (≥ 4 cm) and presence of pseudoaneurysms predispose to hemorrhagic complications.*

Renal CECT (AML)



Renal Arteriogram (AML)



TERMINOLOGY

Definitions

- **Ablation**: Percutaneous direct local tumor destruction introducing/using device to cause cell death
  - **Energy-based ablation**
    - Radiofrequency ablation (RFA): Heat-based
      - Most common modality used for renal ablation
    - Cryoablation: Freezing/thawing cycle
      - Also frequently used modality for renal ablation
    - Microwave ablation: Heat-based cytotoxicity
      - Offers faster ablation times; less susceptibility to thermal heat sink effect
    - High-intensity focused ultrasound: Coagulation necrosis caused by high-intensity ultrasound beam focused on small tissue volume
      - Respiratory motion/overlying ribs problematic
    - Irreversible electroporation: Electrical disruption of integrity of cell membrane
      - Promising preliminary animal/human data, still investigational
  - **Chemical ablation**
    - Inconsistent cellular necrosis in renal tumors
      - Not routinely used for renal ablation
- **Embolization**: Transcatheter introduction of intravascular agent for devascularization/occlusion
  - Bland embolization: Transcatheter arterial embolization without chemotherapeutic agent
  - Transcatheter ethanol injection: Denatures cellular proteins/causes small vessel thrombosis
- **Thermal heat sink effect**: Thermal energy needed to achieve cytotoxicity is dissipated
  - Convective heat transfer to adjacent structures
    - Blood flow in vessels abutting tumor prevents adequate heat generation for effective ablation

PREPROCEDURE

Indications

- **Renal cell carcinoma**
  - Nonsurgical candidate/does not desire surgery
  - Genetic disorders increasing likelihood of multiple bilateral renal tumors (i.e., von Hippel-Lindau syndrome, tuberous sclerosis, Birt-Hogg-Dubé syndrome)
  - Solitary kidney
  - Renal insufficiency
  - Appropriately sized lesion for ablation
    - Best ablation results in tumors < 4 cm
- **Angiomyolipoma (AML)**
  - **Elective/prophylactic treatment**
    - Tumor > 4 cm
      - Size is crude measure of rupture potential (large/predominantly fatty tumor unlikely to bleed)
      - 1 bleeding episode/3.4 pt/yr if AML > 4 cm
    - Nonruptured aneurysms > 5 mm
      - More predictive of rupture than tumor size
    - Symptomatic patient
      - Pain/tenderness/mass effect/hemorrhage
  - **Emergent treatment**
    - Acute rupture/hemorrhage
      - Ruptured AML aneurysm may present in shock
      - Rupture spontaneously or after minimal trauma
      - Successful intervention possible even if unstable

Contraindications

- **General**
  - Uncorrectable coagulopathy
  - Lack of safe access to lesion
- **Ablation**
  - Lesion with high risk of incomplete ablation
    - Large size (≥ 4 cm)
    - Proximity to central vascular structures
      - Heat sink effect
  - Lesion near structures at risk of thermal injury
    - Renal hilar structures (e.g., vessels, renal collecting system)
    - Liver, bowel

Preprocedure Imaging

- CT/MR
  - Determine lesion location
    - Least challenging location: Posterior exophytic
    - Most challenging location: Central hilar
  - Ascertain lesion size and margins
    - Ideal lesion ≤ 3 cm but acceptable results if < 4 cm
    - Risk of incomplete ablation rises with lesion size
  - 3D margins/tumor volume should be determined
    - Multiplanar reformatted images helpful
  - Evaluate lesion proximity to collecting system
    - Pyeloperfusion of cool D_5W through externalized ureteral stent may protect ureter
  - Evaluate lesion proximity to vascular structures
    - Consider additional treatment in areas at risk
  - Plan site/path of probe insertion
- CTA
  - Very useful prior to transcatheter embolization
    - May show dominant vascular supply to tumor
    - May demonstrate arteriovenous shunting
      - Implications for safety of embolization
- US
  - Must document satisfactory visualization of lesion with sonography if US guidance considered
- DSA
  - Evaluation of tumoral hemodynamics
    - Potential impact on choice of embolic agent/safety profile of transcatheter embolization
  - Imaging guidance during transcatheter embolization

Getting Started

- Things to check
  - Procedure indications
  - Current medications
    - Any anticoagulant or antiplatelet agents
  - Allergies
  - Pacemaker/defibrillator
    - Pre-RFA electrophysiologist evaluation
  - Laboratory parameters
    - Complete blood count, platelet > 50,000/μL
    - Coagulation profile
      - International normalized ratio ≤ 1.5
      - Normal prothrombin time, partial thromboplastin time

    - Estimated glomerular filtration rate (eGFR)
      - Reduced eGFR may impact prophylactic antibiotic regimen/ability to give IV contrast
  - Biopsy: Up to 25% of renal masses < 3 cm benign
- Medications
  - Anesthesia
    - Adequate procedural sedation
      - Fentanyl, midazolam, Demerol typically used
    - Anesthesiology assistance if necessary
  - Prophylactic antibiotics: No consensus
    - Administer if pyeloperfusion required
    - Regimens vary
      - Ceftriaxone (1 g) or levofloxacin (500 mg)

PROCEDURE

Patient Position/Location

- Best procedure approach
  - **Ablation**: Most comfortable position that also facilitates procedural access
    - Ipsilateral decubitus: Optimal for upper pole masses
      - Lung displaced, reducing risk of pneumothorax
      - Ipsilateral kidney moves less
    - Prone: Suitable for lower pole masses
      - Subcostal approach; angle gantry if necessary
    - 30° oblique (ipsilateral side up): For anterior masses
      - Allows movement of bowel from ablation zone
    - Supine: Suitable for anterior/lateral masses
      - Liver, spleen, colon should not be in trajectory
  - **Embolization**: Transfemoral arterial access

Equipment Preparation

- Hydrodissection
  - Consider nonionic contrast diluted in D_5W (e.g., 5-10 mL Isovue-370 in 500 mL D_5W)
    - May improve hydrodissection margin delineation
- Pyeloperfusion
  - Requires urology to place externalized ureteral stent
  - Connect 1-L bag of cool D_5W to ureteral stent
    - Start slow drip infusion (e.g., rate of 1-2 drops/s)

Procedure Steps

- **General**
  - Perform preliminary CT and localize target
    - Verify stent position for pyeloperfusion
    - Reconfirm planned access route is appropriate
  - Reassess any other ancillary requirements (e.g., hydrodissection/change in patient position)
  - Sterilely prepare/drape skin
  - Administer 1% lidocaine local anesthetic
    - Dermatotomy with #11 scalpel at skin entry site
  - If needed, may perform biopsy prior to ablation
    - Consider biopsy in separate prior session
      - Exclude possibility of benign mass
      - Trial run for ablation procedure
- **Hydrodissection**
  - Insert Longdwell needle into plane between planned ablation margin and structure at injury risk
  - Connect sheath to extension tubing/3-way stopcock
  - Instill 10 mL hydrodissectant
    - Should flow easily; if resistance encountered, needle tip may be intraparenchymal; adjust tip
  - Perform CT to evaluate effect of hydrodissection
- **Ablation**
  - **General**
    - Ablation zone should completely encompass tumor with additional 0.5-1 cm margin
    - If lesion imperceptible on noncontrast scan
      - Place needle/probe using anatomic landmarks
      - Perform intravenous contrast enhanced scan
      - Adjust probe placement accordingly
    - At end of ablation, obtain postprocedure imaging
      - Assess for hemorrhage/other complications
  - **RFA/microwave ablation**
    - Place grounding pads on legs; both at same level
      - Risk of skin burn if not same level
    - Place radiofrequency probe(s)/microwave antenna(s) in lesion
      - Confirm position with repeat imaging
    - Activate generator; activate ablation system
      - Some patients may sense pain during ablation
    - At end of ablation cycle, reposition probe/antenna
      - Overlapping ablations may be needed to achieve desired ablation volume
      - Image after each applicator repositioning
  - **Cryoablation**
    - Advance cryoprobes into lesion
    - Multiple cryoprobes usually necessary
      - Smaller ablation zone per probe than RFA
      - Position probes 1 cm from tumor margin
      - Perform scan after each probe placement to verify position; generally space 1.5 cm apart
    - Ablation zone visible on intraprocedural CT/MR
      - Allows more confident tumor margin coverage than RFA; no need for IV contrast to verify
    - Activate freeze cycle
      - Duration: 10-15 min
      - Scan to assess ice ball size
      - Ice ball formation hypodense on CT
    - Goal is ice ball margin at least 5 mm past desired ablation margin
      - Ice ball margin represents 0°C isotherm (insufficient for cell death)
      - -20°C temperature 3 mm deep to ice ball margin; lethal zone ~ 5 mm deep
    - Ice ball should be 2 cm larger in diameter than tumor to achieve adequate margin
      - Consider additional cryoprobes if small ice ball
    - Activate passive thaw cycle (8-10 min)
    - Repeat freeze cycle
      - At end of 2nd freeze cycle, active thaw
    - Remove cryoprobes gently with twisting motion
      - Aggressive removal risks parenchymal fracture
    - May note backbleeding requiring manual pressure
      - Cryoablation lacks coagulative effects of RFA
    - Perform postprocedure scan
  - **Embolization**
    - Catheterize artery most likely supplying tumor
    - Obtain/analyze DSA images
      - Determine appropriate/optimal embolic agent

      - Significant arteriovenous shunting may influence choice/appropriateness of particles
    - Selectively catheterize dominant arterial branch feeding tumor; may use coaxial microcatheter
    - Obtain DSA; proceed with embolization
      - Embolize as selectively as possible
      - Embolization agent: Particles or alcohol
      - Endpoint: Stasis within target circulation

Alternative Procedures/Therapies

- Surgical
  - Open/laparoscopic thermal ablation
  - Open/laparoscopic/robotic partial or complete nephrectomy

POST PROCEDURE

Things to Avoid

- Thermal injury to adjacent structures (ablation)
  - Renal collecting system/ureter
  - Bowel/solid organs (e.g., pancreas/spleen/liver)
- Nontarget embolization (transcatheter embolization)

Postprocedure Imaging (Ablation)

- Need serial follow-up imaging to assess success
- Imaging interval institution-dependent
  - Sample algorithm: 3, 6, 9, 12 months; then annually
- Normal postablation protocol and findings
  - NECT/CECT (nephrographic/excretory phases)
    - Subtraction images helpful to assess enhancement; multiplanar reformations helpful to assess margins
    - Hypodense ablation zone; may be wedge-shaped
    - Hyperdense areas due to coagulated proteins
    - Ablation zone larger than index lesion
      - May see enlargement for up to 6 months
      - Later enlargement suspicious for progression
  - MR
    - Lesion variable in intensity on T1WI
    - Lesion hypointense on T2WI
- CT/MR nonenhancement correlates with tumor necrosis
- Residual disease or local progression manifested by
  - Nodular type: Peripheral nodules of enhancement
  - Peripheral enhancing crescent
  - Morphologic changes/growth on serial imaging
- Benign ancillary findings
  - Thin rim (< 5 mm) of periablational enhancement
    - MR may show T2 hyperintense rim
    - Most prominent at 1 month; may last 6 months
  - Perirenal or pararenal fat stranding
    - May coalesce over serial scans into dominant halo oriented parallel to surface of kidney
    - May displace axis of kidney
      - May complicate comparison across studies
  - Fatty replacement of zone of ablation
  - Extracalyceal contrast on delayed images; not important if nonobstructed distal collecting system
  - Liquefactive necrosis
    - Thermal ablation generally causes coagulative necrosis; rarely, may see liquefactive necrosis
      - Hyperintense on T2WI
      - Fat-fluid levels/internal debris
    - Distinguish from recurrent tumor by lack of enhancement
    - Consider biopsy in challenging cases

OUTCOMES

Complications

- Most feared complication(s)
  - Ureteral stricture
    - May require nephrostomy, ureteral stent
    - Urinoma may require separate drain
  - Bowel perforation
- Immediate/periprocedural complication(s)
  - **Ablation**
    - Hemorrhage
    - Pleural effusion/pneumothorax
    - Skin burn
      - Overlying treatment site, at grounding pad site
      - Shave skin/ensure good contact to reduce risk
    - Cutaneous nerve injury (paresthesias)
      - Lumbar plexus, i.e., ilioinguinal (L1), genitofemoral (L1-2), lateral femoral cutaneous (L2-3) nerves
  - **Embolization**
    - Periprocedural aneurysm rupture in AML
    - Nontarget embolization/renal parenchymal loss
      - If superselective embolization not possible
    - Postembolization syndrome (AML embolization)
      - Inflammatory response to necrotic tissue
      - Affects 90% of AML embolization patients
      - Symptoms: Pain, nausea, vomiting, fever
      - Treat with IV fluids, analgesics, antipyretics, antiemetics, tapered dose of prednisone
    - Arterial access site complications
- Delayed complication(s)
  - Tract seeding (exceedingly rare)
  - Pseudoseeding
    - Inflammatory nodules along applicator tract; consider biopsy if fails to resolve on serial imaging
  - Postablation syndrome

Expected Outcomes

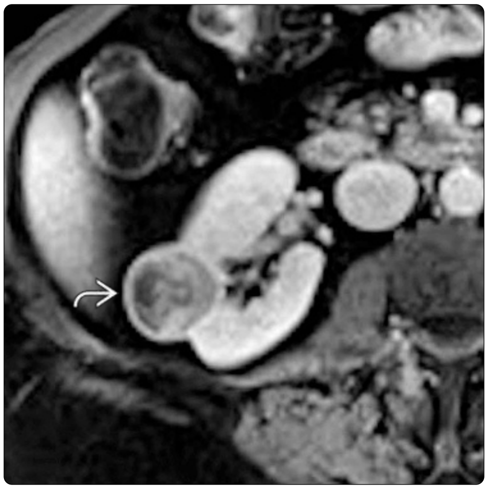
- **Ablation**
  - Complete necrosis in masses ≤ 4 cm: ≥ 90%
  - Reported residual/recurrent tumor incidence
    - Single RFA: 13.4%
    - Single cryoablation: 3.9%
    - After repeat ablation (both modalities): 4.2%
  - Overall 2-year survival: 82.5%
- **Embolization**
  - Success rate of AML embolization: 90-100%
  - Tumor does not disappear; decreases by 40-66%
    - Angiomyogenic component decreases > fat
    - Fatty tissue relatively insensitive to embolization
  - Minimal loss of surrounding normal parenchyma

SELECTED REFERENCES

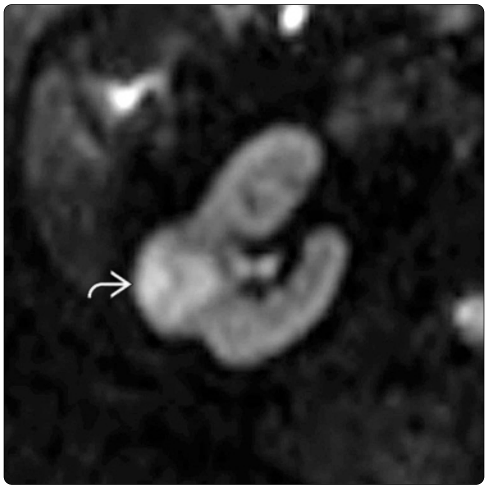
1. Potretzke AM et al: Re: Thompson RH et al. Comparison of partial nephrectomy and percutaneous ablation for cT1 renal masses. Eur Urol 2015;67:252-9. Eur Urol. 67(2):e19-20, 2015
2. Moreland AJ et al: High-powered microwave ablation of t1a renal cell carcinoma: safety and initial clinical evaluation. J Endourol. 28(9):1046-52, 2014

(Left) *Axial T1 C+ FS MR demonstrates enhancement of a focal right renal mass* ➔*. There is well-defined peripheral rim enhancement.* **(Right)** *Axial DWI MR in the same patient demonstrates restricted diffusion, indicated by hyperintensity, within the right renal mass* ➔*. Restricted diffusion is seen in renal cell cancers and may be helpful in differentiating these from benign lesions.*

Cryoablation: Right Renal Mass (Initial MR)

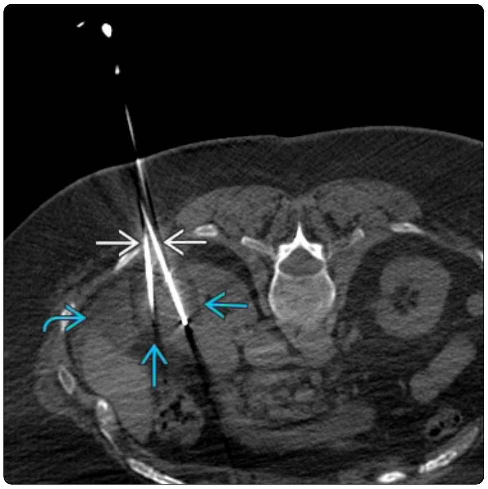


Cryoablation: Right Renal Mass (Initial MR)

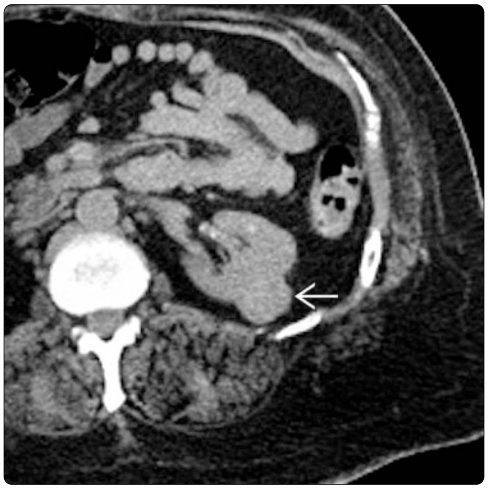


(Left) *Intraprocedural NECT demonstrates the cryoprobes* ➔ *well situated within the renal mass. There is a well-defined ice ball* ⇨ *with adequate margins. The renal mass is separated from the liver with hydrodissection* ⇨ *performed prior to ablation.* **(Right)** *Axial NECT in a different patient demonstrates an exophytic, isodense left renal mass* ➔*. The location of this mass makes it a good candidate for percutaneous cryoablation.*

Cryoablation: Right Renal Mass (Hydrodissection and Ablation)

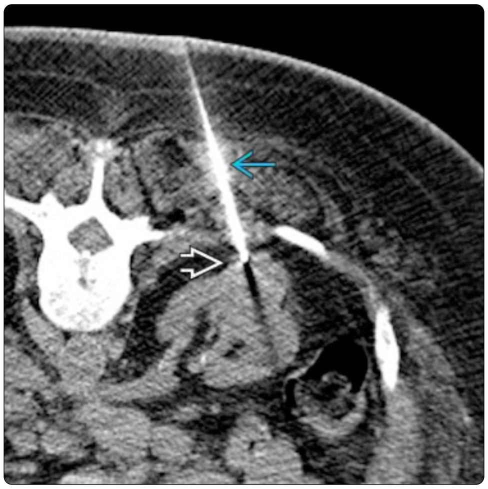


Cryoablation: Left Renal Mass (NECT)

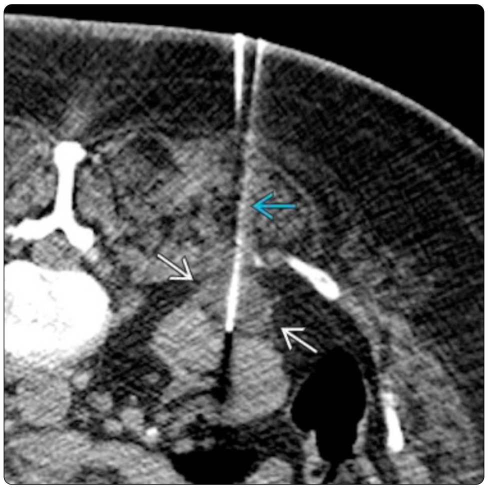


(Left) *Intraprocedural NECT in this patient demonstrates the cryoprobe* ⇨ *at the posterior margin of the tumor* ➔ *during CT-guided placement.* **(Right)** *Intraprocedural NECT demonstrates the cryoprobe* ⇨ *within the tumor during the freeze cycle of the ablation. The margins of the ice ball are well visualized* ➔*. The freeze cycle is typically followed by a thaw cycle and then a refreeze cycle.*

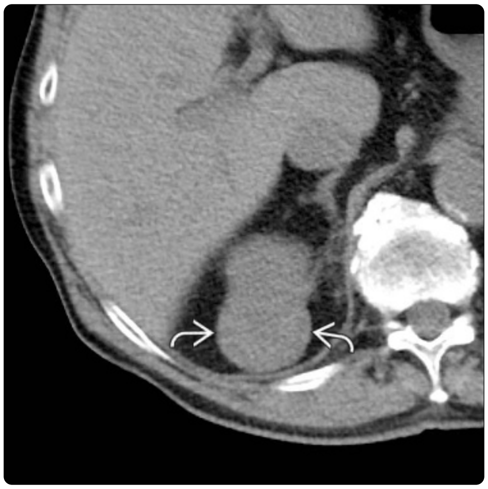
Cryoablation: Left Renal Mass (Cryoprobe Placement)



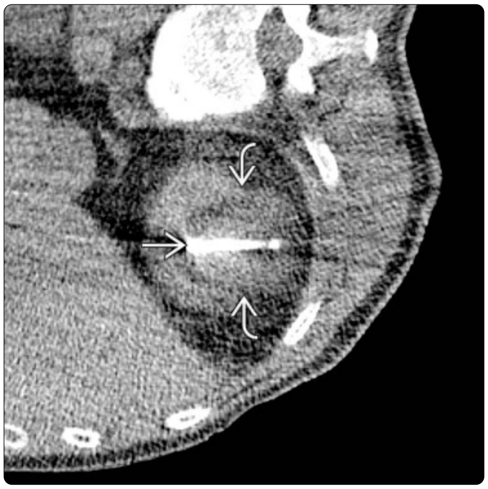
Cryoablation: Left Renal Mass (Treatment Ice Ball)



Cryoablation of Renal Cell Carcinoma (Initial NECT Evaluation)

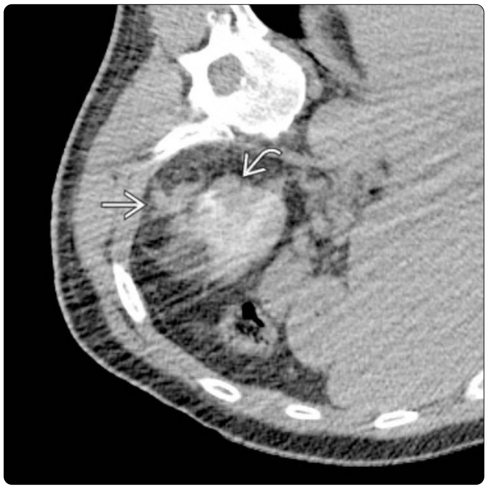


Cryoablation of Renal Cell Carcinoma (Hypodense Ice Ball During Freeze Cycle)

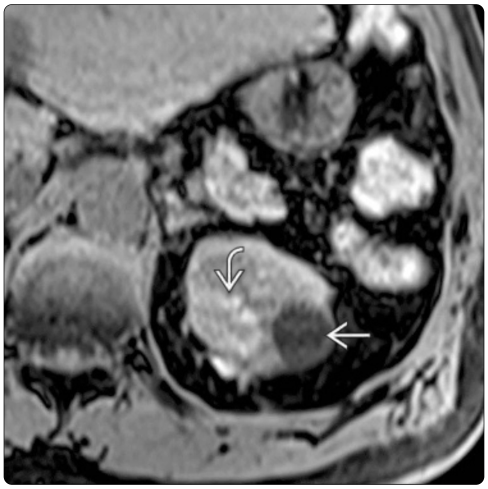


(Left) *In another patient, a renal mass ↪ is located posteriorly in the upper pole of the right kidney. The patient was not a surgical candidate due to comorbidities, and the renal mass was an appropriate size for ablation.* **(Right)** *Axial NECT 10 min into cryoablation freeze cycle shows 1 of the cryoprobes ➡ and hypodense ice ball ↪ encompassing the lesion. Lethal zone is 5 mm internal to ice ball margin. Freeze cycle was followed by passive thaw and a repeat freeze cycle. Cryoablation may cause less pain than radiofrequency ablation (RFA).*

Post RFA of Renal Cell Carcinoma: Immediate (Postprocedural NECT)

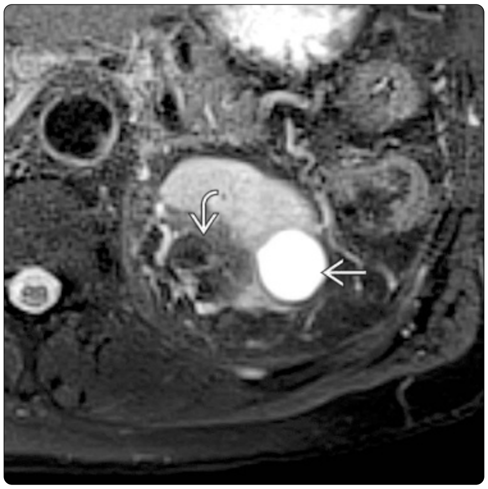


Post RFA of Renal Cell Carcinoma: 1 Month (MR)

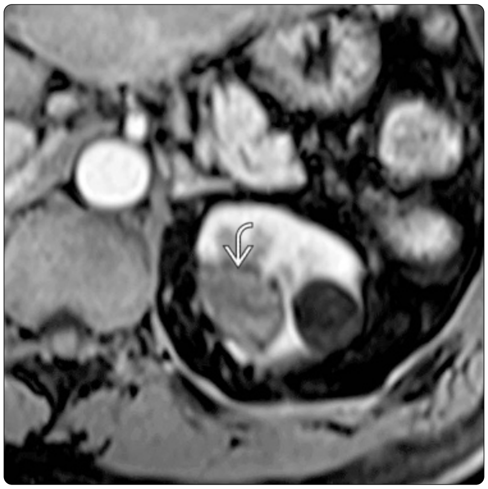


(Left) *Overlapping RFAs of a renal cell carcinoma were performed with adjustment of the probe position between treatments. Immediate postprocedure CT demonstrates a small collection of perirenal blood products ➡ adjacent to the ablation zone ↪ along the probe trajectory, a typical finding.* **(Right)** *Axial T1 FS MR performed 1 month following the RFA demonstrates hyperintensity ↪ in the ablation zone, which is compatible with coagulation necrosis. A simple renal cyst ➡ is also visible.*

Post RFA of Renal Cell Carcinoma: 1 Month (MR)

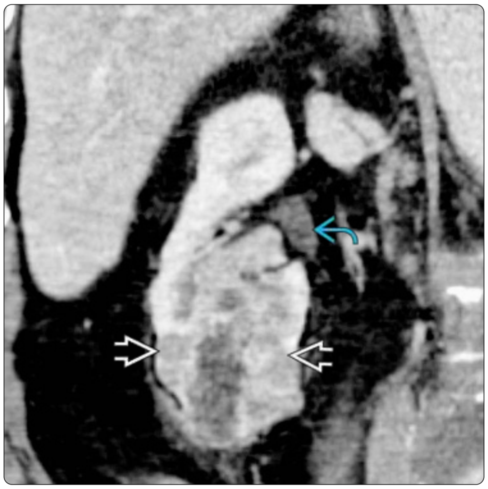


Post RFA of Renal Cell Carcinoma: 1 Month (MR)

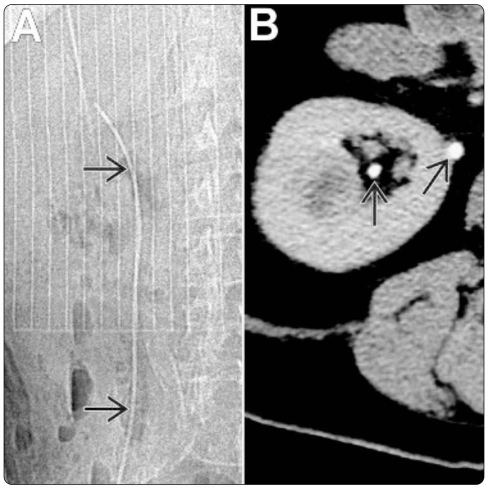


(Left) *Axial T2 FS MR from the 1-month posttreatment MR shows predominantly T2-hypointense signal ↪ in the ablation zone, which is an expected finding. Note the T2-hyperintense cyst ➡.* **(Right)** *Axial T1 C+ FS MR shows no enhancement ↪ in the ablation zone, which is the best imaging correlate of tumor necrosis. A thin rim (< 5 mm) of enhancement may occasionally be seen, which is a benign ancillary finding.*

(Left) *Coronal CECT shows a large lower pole renal mass ➡. Note that the mass extends centrally and is in close proximity to the renal pelvis ↪. There is risk of nontarget thermal injury during ablation, which could result in ureteral stricture &/or urinoma.* **(Right)** *(A) Scout and (B) axial images from a preliminary CT for RFA show an externalized ureteral stent ⇨ placed by a urologist prior to the procedure. Pyeloperfusion with D_5W provides protection of the renal collecting system from thermal injury during ablation.*

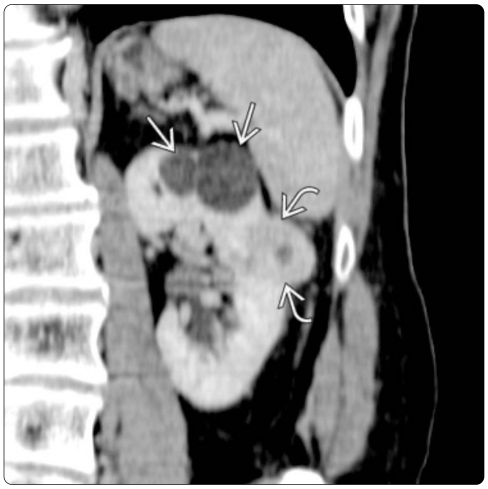


Pyeloperfusion: RFA Planning (Potential Risk of Thermal Injury)

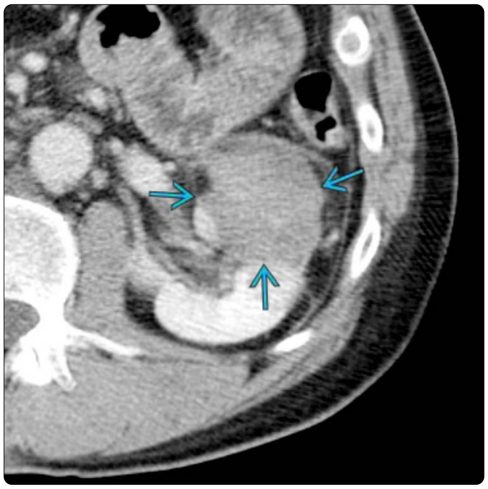


Pyeloperfusion: RFA Planning (Placement of Ureteral Stent)

(Left) *Coronal CECT reconstruction prior to planned RFA demonstrates a solid renal mass ➡ in the interpolar region of the left kidney. A pair of renal cysts ➡ are also evident. Using a cluster electrode, several overlapping RFA treatments were performed.* **(Right)** *Axial CECT obtained 3 months after the RFA demonstrates a nonenhancing zone of ablation ⇨, which appears both to completely encompass the lesion and to extend beyond it with a generous surrounding margin.*

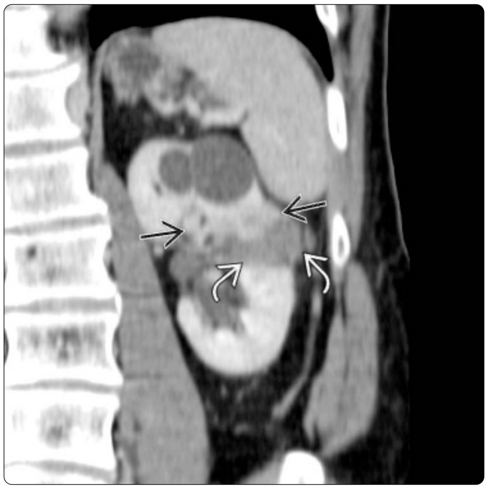


Residual Disease After RFA (CECT Prior to Initial Ablation)

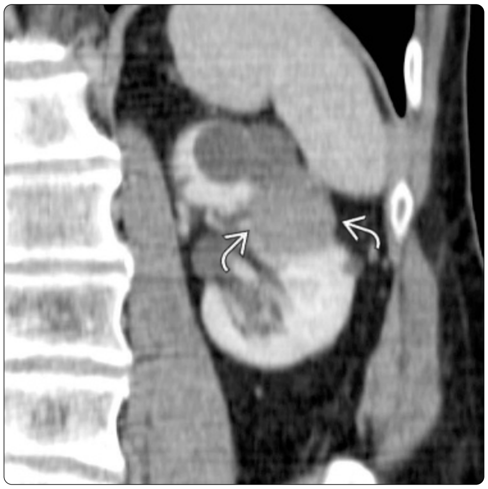


Residual Disease After RFA (CECT After Initial Ablation)

(Left) *Although the axial images showed what appeared to be a satisfactory result, a coronal image from the same CT shows irregular enhancement ⇨ along the superior margin of the ablation zone ↪. Review of multiplanar reformats is critical in assessing all ablation zone margins.* **(Right)** *Repeat RFA of the residual disease was performed. CECT 1 month later shows no enhancement in the ablation zone ↪ consistent with tumor necrosis.*

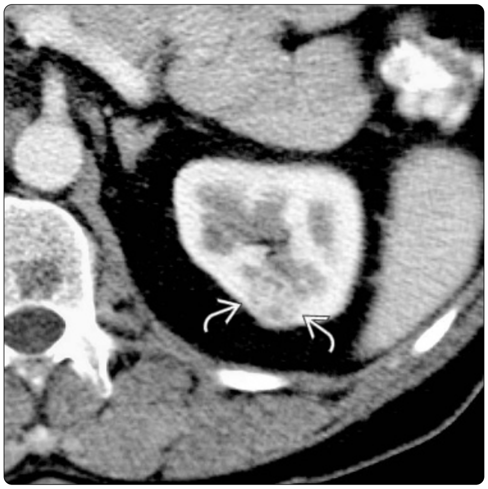


Residual Disease After RFA (Coronal CECT After Ablation)

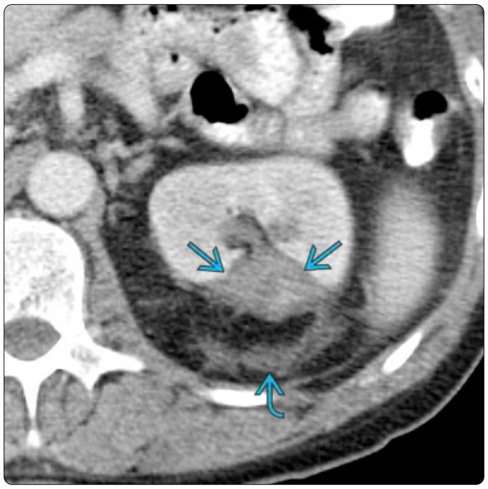


Residual Disease After RFA (Coronal CECT After Retreatment)

Benign Postablation Ancillary Findings (Initial CECT Evaluation Before RFA)

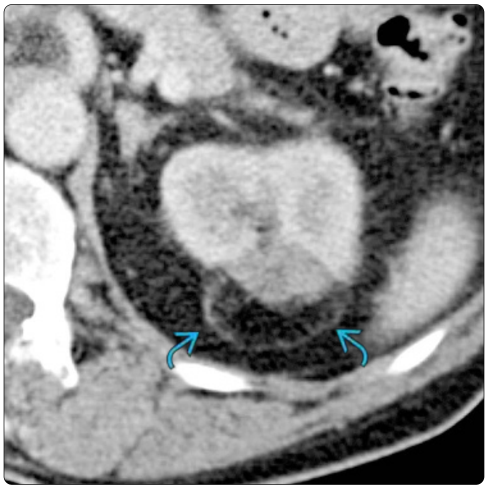


Benign Postablation Ancillary Findings (Soft Tissue Stranding)

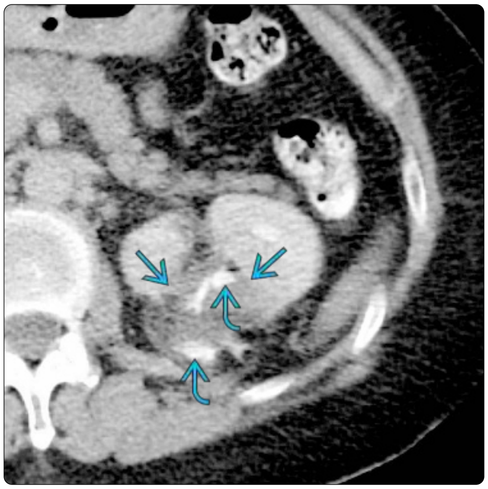


(Left) *Axial CECT obtained prior to a planned RFA demonstrates a small, solid, enhancing mass ➡ in the posterior aspect of the left kidney.* **(Right)** *One month after RFA, CECT demonstrates a lack of enhancement in the ablation zone ⇨. However, there is soft tissue stranding ↪ in the perirenal fat oriented parallel to the renal contour. This is a typical benign finding that occurs after ablation and should not prompt concern for tract seeding.*

Benign Postablation Ancillary Findings (Fat Halo 9 Months After RFA)

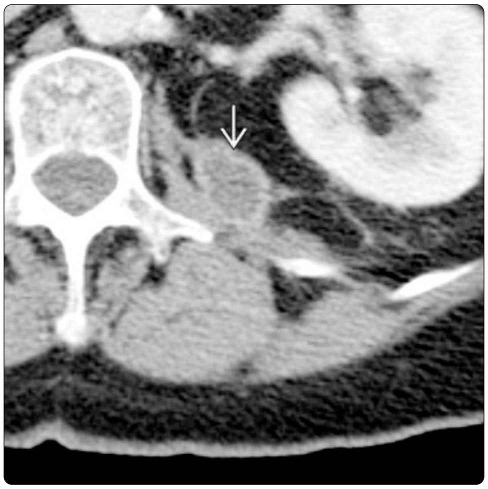


Benign Postablation Ancillary Findings (Extracalyceal Contrast 9 Months After RFA)

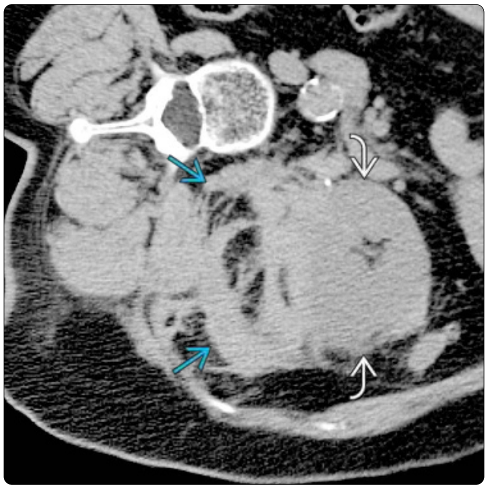


(Left) *Nine months after RFA, CECT shows that there has been coalescence of the perirenal stranding into a fat halo ↪. Both the ablation zone and the fat halo may decrease in size over time.* **(Right)** *During the excretory phase, strands of extracalyceal contrast ↪ can accumulate in the ablation zone ⇨. This may be seen on serial CECT exams. In the absence of downstream obstruction in the renal collecting system, this is a benign ancillary finding.*

Benign Postablation Ancillary Findings (Probe Tract Pseudoseeding After RFA)



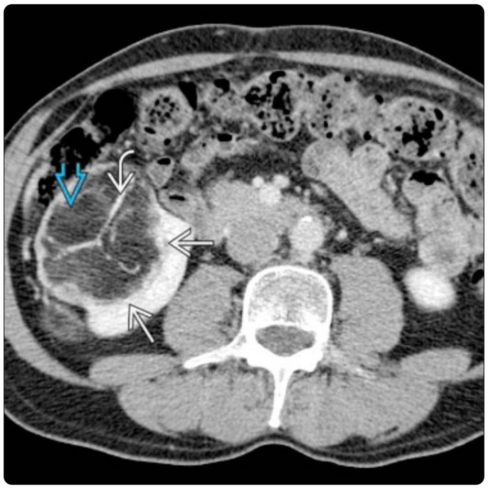
Complication: Perirenal Hematoma Formation After RFA



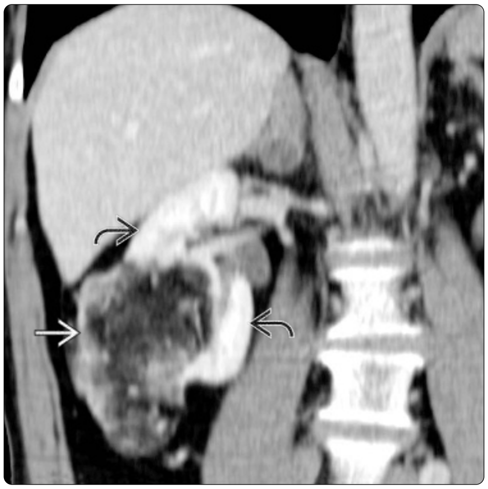
(Left) *A different patient's CECT obtained 1 month post RFA shows a rim-enhancing density ➡ posterior to the kidney, within the RFA probe tract. This involuted over serial CT examinations. While true tumoral seeding of the tract is exceedingly rare, enlarging or persistent suspicious soft tissue may necessitate biopsy.* **(Right)** *Axial NECT obtained immediately after RFA shows a hematoma ⇨ adjacent to the kidney ↪. Perirenal hemorrhage can be seen after ablation; rarely, blood loss is significant enough to require or prolong hospital admission.*

(Left) *Axial CECT in a patient with a known AML demonstrates a large mass ➡ arising from the lower pole of the right kidney. The mass has a large fat component ⇨ but also contains numerous enhancing vascular structures ↪, which is typical of AML.* **(Right)** *Reformatted coronal CECT shows the large right renal mass ➡ and its relationship to the normal renal parenchyma ↪. There is an increased risk of spontaneous hemorrhage for lesions > 4 cm.*

AML Embolization (Initial CECT Evaluation)

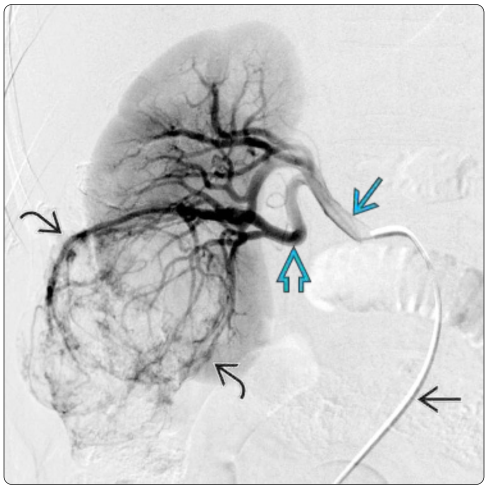


AML Embolization (Initial CECT Evaluation)

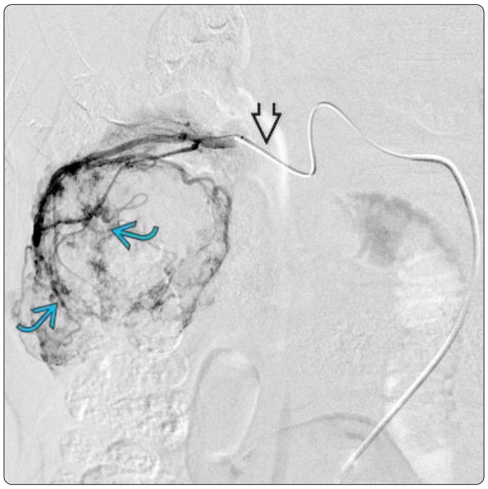


(Left) *Selective DSA via Cobra catheter ⇨ placed in the right renal artery ⇨ shows a prominent vascular component to the AML and that the tumoral blood supply ↪ arises from an enlarged lower pole arterial branch ⇨.* **(Right)** *Superselective DSA via a coaxial microcatheter ⇨ prior to embolization shows typical intratumoral vascularity ↪ but no arterial aneurysms. The goal of AML embolization is tumor devascularization in order to limit or prevent growth &/or spontaneous rupture.*

AML Embolization (Initial DSA Evaluation)

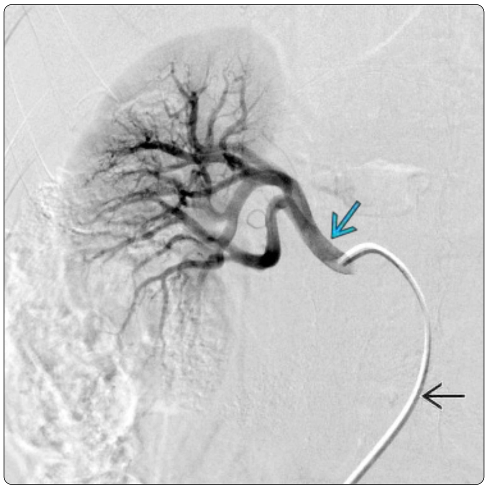


AML Embolization (Superselective DSA via Microcatheter)

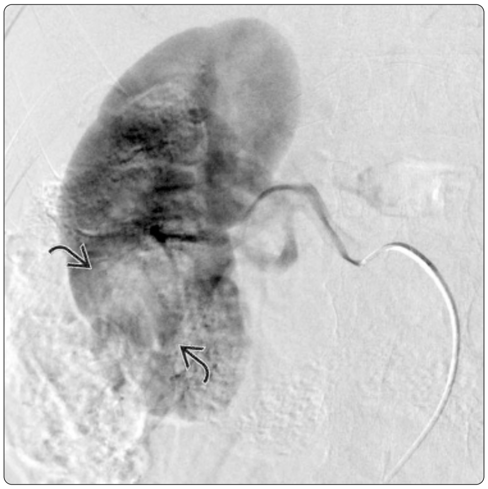


(Left) *After embolization with 300- to 500-µm particles via the microcatheter, a repeat renal artery ⇨ DSA was performed via the 5-Fr catheter ⇨. The arterial phase shows successful devascularization. ETOH mixed with lipiodol is also frequently used for AML embolization.* **(Right)** *Delayed parenchymal-phase DSA shows that there has been satisfactory preservation of the normal renal tissue, with an area of slight hypoperfusion ↪ corresponding to the treated AML.*

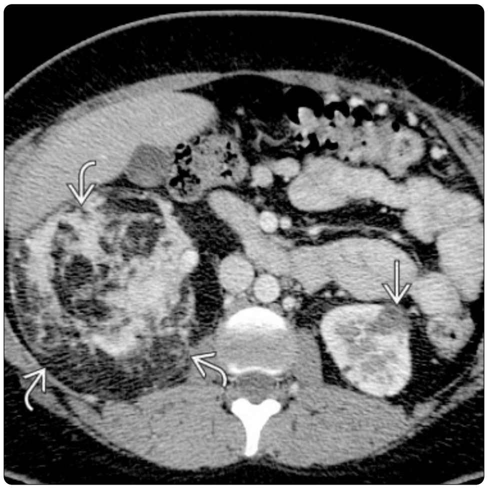
AML Embolization (Postembolization Arterial Phase)



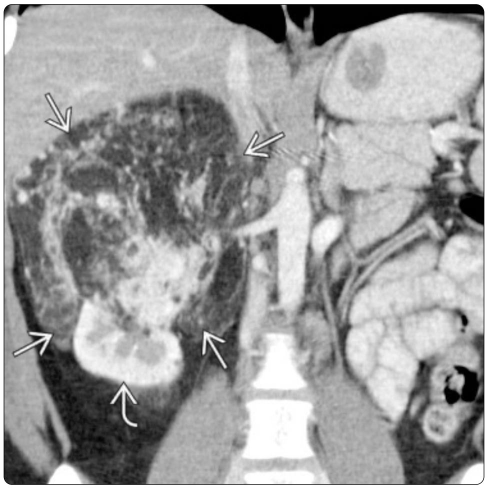
AML Embolization (Postembolization Parenchymal Phase)



Massive AML Embolization (Initial CECT Evaluation)

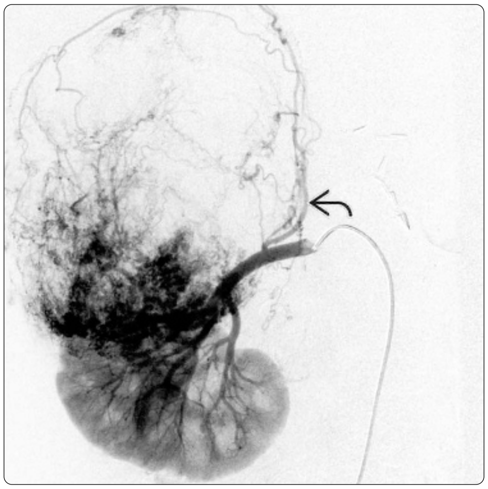


Massive AML Embolization (Initial CECT Evaluation)

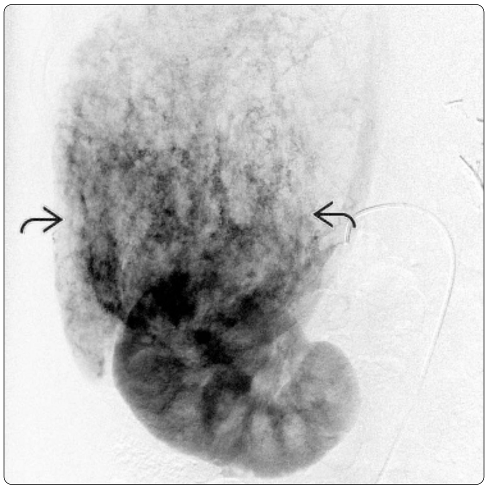


(Left) *Axial CECT in a patient with tuberous sclerosis shows an extremely large, enhancing, fat-containing mass* ↪ *replacing the upper pole of the right kidney, consistent with AML. A much smaller 2nd AML* ➡ *is seen in the left kidney.* **(Right)** *Coronal CT reconstruction shows the massive size of the AML* ➡ *and the extent of residual normal renal parenchyma* ↪*. It is important to preserve normal renal tissue during embolization, particularly given bilateral AMLs.*

Massive AML Embolization (Renal Arteriogram, Arterial Phase)

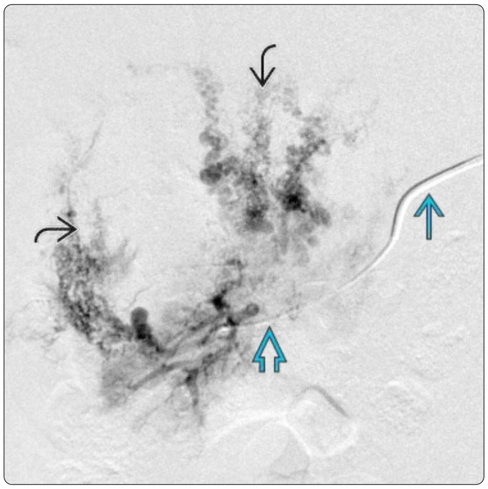


Massive AML Embolization (Renal Arteriogram, Parenchymal Phase)

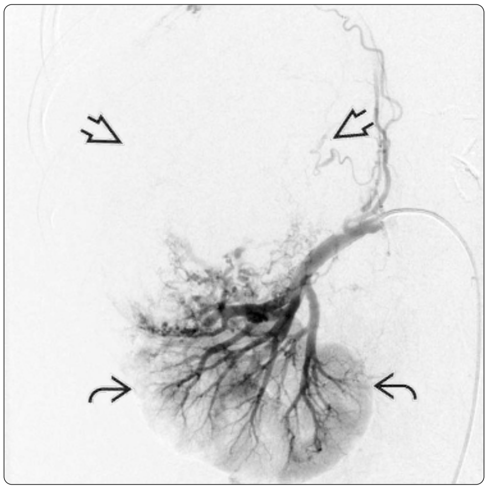


(Left) *Arterial-phase DSA provides important information regarding the arterial supply to the tumor and guides embolization. The main vascular supply to this AML is through middle and upper pole renal branches, but there are also capsular branches that contribute* ↪*.* **(Right)** *Delayed parenchymal-phase DSA shows the tremendous vascularity* ↪ *of this mass. Although size is a predictor of the rupture potential of an AML, tumor composition is important, as predominantly fatty tumors are less likely to bleed.*

Massive AML Embolization (Distal Particle Embolization via Microcatheter)



Massive AML Embolization (Postembolization Renal Arteriogram)



(Left) *A microcatheter* ⇨ *has been coaxially introduced through the Cobra catheter* ➡ *and has been positioned selectively beyond the arteries to the normal renal parenchyma. DSA shows only tumor vascularity* ↪ *from this catheter position. Particle embolization was performed from this location. Additional branches supplying the tumor were also embolized.* **(Right)** *Right renal DSA following embolization shows marked tumor devascularization* ⇨ *and preservation of the residual normal renal parenchyma* ↪*.*

KEY FACTS

PREPROCEDURE

- Stage I non-small cell lung cancer (nonoperable/salvage therapy)
    - Oligometastatic disease
    - Devascularization prior to surgery

PROCEDURE

- **Ablation**
    - Perform preliminary CT and localize target
    - Ideal lesion for ablation ≤ 3 cm
    - Introduce probe into soft tissues
    - Obtain NECT; assess/correct trajectory
    - Advance probe across pleura into lung parenchyma toward nodule
    - Minimize number of pleural surfaces/fissures crossed; reduces pneumothorax risk
    - Position probe tip within nodule; perform ablation
- **Embolization**
    - Obtain/analyze DSA images for embolization appropriateness/safety, optimal embolic agent
    - Selectively catheterize dominant arterial branch feeding tumor; may use coaxial microcatheter

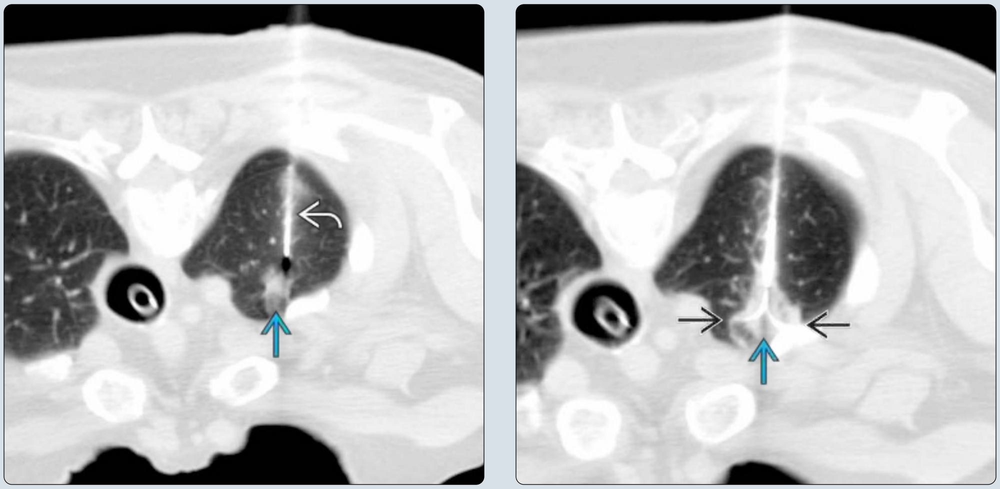
POST PROCEDURE

- Serial follow-up imaging to assess success
    - 1 algorithm: 1, 3, 6, 9, 12 months, then annually alternating CT and PET/CT (if FDG-avid disease)
    - Postablation inflammatory FDG uptake is present on early PET for up to several months, inhibiting ability to distinguish benign healing vs. residual/recurrent tumor

OUTCOMES

- **Ablation**
    - Cancer-specific survival for lesions < 3 cm may ↑ 90%
    - Predictors of complete tumor necrosis
        - Mass < 3 cm
        - Peripheral halo (> 5 mm) of ground-glass opacity surrounding nodule at end of treatment

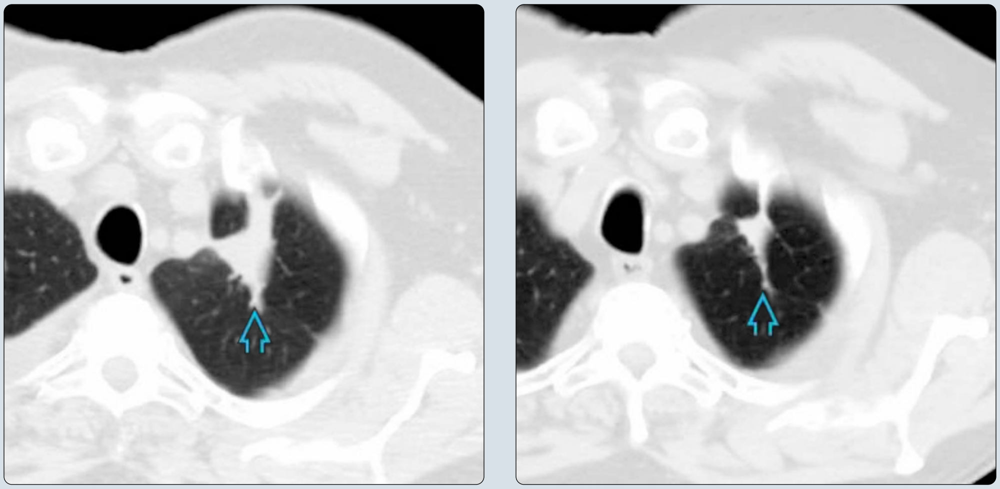
(Left) *A 78-year-old man with biopsy-proven T1 N0 M0 left apical adenocarcinoma refused surgical resection and underwent percutaneous ablation of the spiculated mass ⇨. Here, the RF probe introducer ↶ is advanced to the periphery of the target mass.* **(Right)** *The RF probe is now deployed within the mass ⇨. The tines → of the probe extend beyond the border of the mass in axial (shown), coronal, and sagittal (not shown) planes. Slight intraparenchymal hemorrhage is seen on the image obtained during ablation.*



Radiofrequency Ablation: Left Apical Mass (Prone Localization of Mass)

Radiofrequency Ablation: Left Apical Mass (Ablation of Mass)

(Left) *This CT has an expected postablation zone ⇨ appearance. Unfortunately, at the 3-month clinical follow-up, the patient complained of arm weakness (dropping coffee cups) and shooting arm pain. Brachial plexus injury is a known complication of apical ablation. Fortunately, arm strength returned shortly thereafter, while pain resolved after ~ 9 months.* **(Right)** *Ablation-related scarring ⇨ within the left apex continues to shrink 8 years later but has never completely resolved. There is no tumor recurrence.*



Radiofrequency Ablation: Left Apical Mass (3-Month Follow-Up CT)

Radiofrequency Ablation: Left Apical Mass (8-Year Follow-Up CT)

Thoracic Ablation and Embolization

TERMINOLOGY

Definitions

- **Ablation**: Percutaneous direct local tumor destruction introducing/using device to cause cell death
  - Energy-based ablation
    - Radiofrequency ablation (RFA): Heat based
      - Aerated lung limits energy deposition
    - Cryoablation: Freezing/thawing cycle
    - Microwave ablation: Heat-based cytotoxicity
      - Less limited by aerated lung than RFA
    - Irreversible electroporation: Electrical disruption of integrity of cell membrane
  - Percutaneous ethanol injection
- **Embolization**: Transcatheter introduction of intravascular agent for devascularization/occlusion
- **Artificial pneumothorax**: Intentional creation of pneumothorax during ablation procedure
  - Displaces ablation zone away from critical structures
    - May be needed if tumor adjacent to large vascular structures (e.g., heart) or phrenic nerve

PREPROCEDURE

Indications

- **Ablation**
  - Stage I non-small cell lung cancer (NSCLC)
    - Not operative candidate
    - Failed surgery, chemotherapy, radiotherapy
    - Palliation
    - Single lung
  - Oligometastatic disease (e.g., colorectal, breast, sarcoma, renal cell carcinoma)
  - Ground-glass nodules: Treatment controversial (e.g., immediate surgery, close follow-up, percutaneous ablation)
- **Embolization**
  - Vascular primary/metastatic tumors
    - Not operative candidate
    - Failed surgery, chemotherapy, radiotherapy
    - Devascularization prior to surgery
    - Palliation

Contraindications

- **General**
  - Uncorrectable coagulopathy
  - Lack of safe access to lesion
- **Ablation**
  - Lesion with high risk of incomplete ablation
    - Large size
    - Large vascular structures
      - Heat-/cold-sink effect
- **Embolization**
  - Renal insufficiency
  - Contrast allergy/anaphylaxis

Preprocedure Imaging

- CT
  - Ascertain lesion size, characteristics, and margins
    - Ideal lesion ≤ 3 cm (ablation)
    - Risk of incomplete ablation rises with lesion size
  - 3D margins and volume should be appreciated
    - Multiplanar reformats helpful
  - Proximity to large vascular structures, phrenic nerve
    - May consider artificial pneumothorax (ablation)
  - Identify vascular supply to lesion (embolization)
    - Demonstrate degree of vascularity
- PET
  - Useful in FDG-avid disease
  - Useful for comparison on posttreatment scans

PROCEDURE

Patient Position/Location

- Best procedure approach
  - **Ablation**
    - Position providing shortest approach to lesion
      - Minimize number of pleural surfaces/fissures crossed; reduces pneumothorax risk
    - Prone preferred over supine position if possible
      - Reduced respiratory motion
      - Posterior interspaces wider than anterior
      - Postprocedure recovery in supine position
      - Need to avoid scapula; place patient's arms by side, internally rotated
      - Sometimes need decubitus position (less stable)
      - Angling gantry may be necessary (avoidance of fissures/negotiation of intercostal space)
    - Approach used should avoid
      - Blebs/bullae/central bronchi
      - Significant vascular structures
  - **Embolization**
    - Transfemoral arterial access typically used

Procedure Steps

- **Ablation**
  - **General**
    - Perform preliminary CT and localize target
    - Reassess need for change in patient position, different approach, artificial pneumothorax
    - Sterilely prepare skin, administer local anesthetic
    - Make dermatotomy at planned access site
    - Introduce probe into soft tissues, not across pleura
      - Obtain NECT; assess/correct trajectory
    - Advance probe across pleura into lung parenchyma toward nodule
    - Position probe tip within nodule
    - Perform ablation
    - Ablation zone should completely encompass tumor with additional 0.5- to 1.0-cm margin
  - **Artificial pneumothorax**
    - If ablation zone adjacent to critical structures
    - Should place ablation probe into lesion first
    - Advance needle into pleural space under CT guidance; location may be far from ablation site
    - Perform test injection via syringe with 10 mL of air
    - Confirm air in pleural space with CT
    - Inject sufficient air to achieve separation
      - Goal > 1-2 cm
  - **RFA/microwave ablation**
    - Overlapping ablations may be needed to achieve desired ablation volume

    - Reposition applicator between each treatment
    - CT scan after applicator repositioning
  - **Cryoablation**
    - Multiple cryoprobes may be necessary
    - Generally space probes 1.5 cm apart
    - Image after each cryoprobe placement
    - Ice ball formation is hypodense on CT
    - Ice ball margin represents 0°C isotherm
      - Temperature at margin insufficient for cell death
    - Lethal zone ~ 5 mm inside edge of ice ball margin
      - Ice ball should be 2 cm larger in diameter than tumor to achieve adequate ablation margin
    - Freeze-passive thaw-freeze cycle
      - 10- to 15-min freeze, 8- to 10-min thaw typical
    - Perform CT scan every 2-5 min during freeze cycle
      - Assess ice ball formation
    - If ice ball too small, consider additional cryoprobes
    - At end of 2nd freeze cycle, active thaw
    - Remove cryoprobes gently with twisting motion
    - Perform postprocedure scan
      - May see ground-glass opacities around tumor
- **Embolization**
  - Introduce arterial access sheath & catheter
  - Catheterize artery supplying tumor (based on CTA)
  - Analyze DSA images
    - Assess for embolization appropriateness & safety
    - Determine optimal embolic agent; particles may be contraindicated with significant AV shunting
  - Selectively catheterize dominant arterial branch feeding tumor; may use coaxial microcatheter
    - Obtain DSA; proceed with embolization
  - Consider additional potential feeding arteries

Alternative Procedures/Therapies

- Other
  - Surgical resection
  - Chemotherapy
  - Radiotherapy
  - Navigational bronchoscopy-guided ablation
  - Direct tumor injection of chemotherapy
  - Transbronchial brachytherapy

POST PROCEDURE

Things to Do

- Obtain chest radiograph 3 hours post procedure
  - Evaluate for pneumothorax

Things to Avoid

- Thermal injury to chest wall, phrenic nerve, brachial plexus
- Nontarget embolization

Postprocedure Imaging (Ablation)

- Need serial follow-up imaging to assess success
- Imaging interval is institution dependent
  - 1 algorithm: 1, 3, 6, 9, 12 months; then annually alternating CT and PET/CT (if FDG-avid disease)
    - Postablation inflammatory FDG uptake is present on early PET for up to several months, inhibiting ability to distinguish benign healing vs. residual/recurrent tumor
- Normal findings
  - Ablation zone larger than index lesion
    - May see enlargement for up to 6 months
      - Later enlargement suspicious for progression
  - Peripheral halo of ground-glass opacity immediately after RFA may resolve at 1-month scan
    - May represent blood products
- CT nonenhancement correlates with tumor necrosis
- Residual disease or local progression manifested by
  - Peripheral enhancing nodule(s)
  - Peripheral/new focus of FDG uptake
  - Morphologic changes/growth on serial scans
- Benign ancillary findings
  - Thin rim of periablation enhancement may be seen up to 6 months after treatment
  - Pleural thickening/effusion
  - Linear opacities along applicator/probe path
  - Cavitation in ablation zone
    - More common in inner 2/3 of lung
    - More common if adjacent to segmental bronchus
    - Cavitation may decrease on subsequent scans
- Assess entire lung for new/other nodules/adenopathy

OUTCOMES

Complications

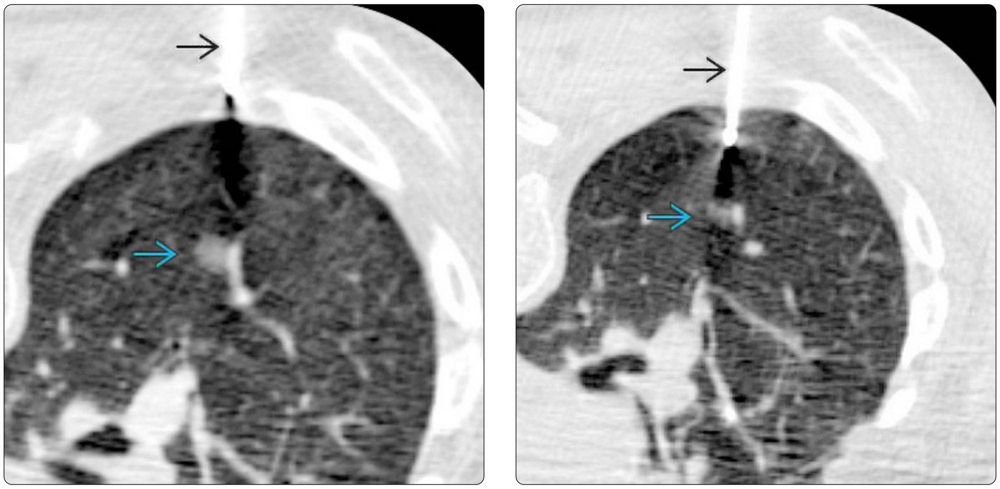
- Most feared complication(s)
  - Pneumothorax (ablation)
    - May require chest tube
    - 12-62% of patients post cryoablation (0-12% with lung collapse, > 30% requiring chest tube insertion)
  - Nontarget embolization
- Immediate/periprocedural complication(s)
  - Pain/pleurisy (ablation/embolization)
  - Pleural effusion (ablation)
  - Hemothorax (ablation)
  - Skin burn (ablation)
    - Overlying treatment site
    - At grounding pad site
      - Shave skin/ensure good contact to reduce risk
- Delayed complication(s)
  - Productive cough with brown sputum (2-4 weeks)
  - Pneumonia; pulmonary abscess
  - Phrenic nerve/brachial plexus injury
  - Bronchopleural fistula
  - Chronic obstructive pulmonary disease exacerbation

Expected Outcomes

- NSCLC, mass < 3.5 cm
  - Cancer-specific survival: 1 year (92%), 2 year (73%)
- Colorectal metastasis
  - Cancer-specific survival: 1 year (93%), 2 year (67%)
- Predictors of complete tumor necrosis
  - Mass < 3 cm; ≥ 5-mm halo of ground-glass opacity surrounding tumor after procedure

SELECTED REFERENCES

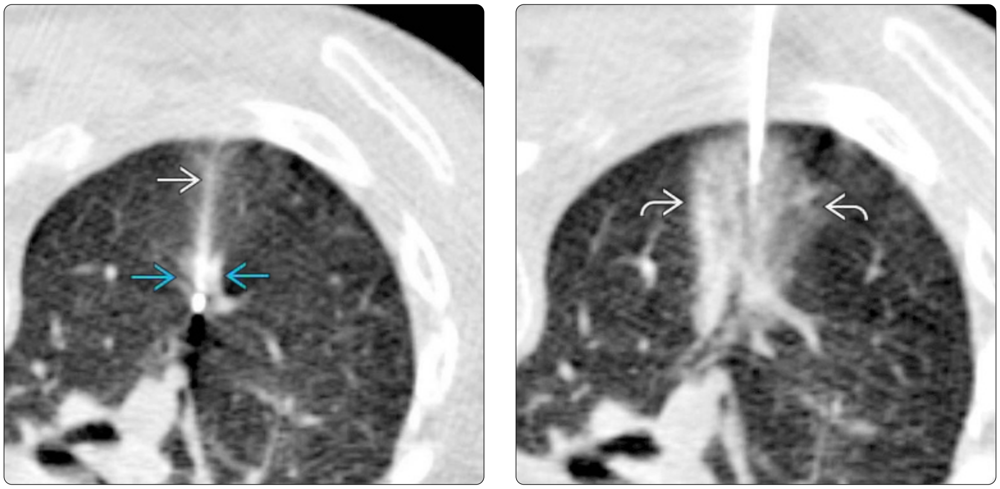
1. Cazzato RL et al: Percutaneous image-guided cryoablation: current applications and results in the oncologic field. Med Oncol. 33(12):140, 2016



Radiofrequency Ablation: Lung Mass (Initial Appearance of Mass)

Radiofrequency Ablation: Lung Mass (Probe Entry Across Pleura)

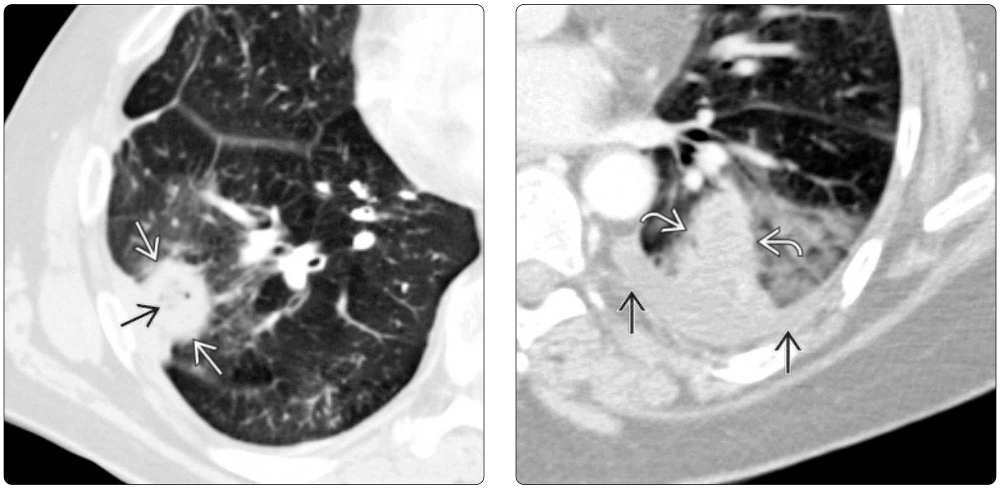
(Left) *An RFA probe* → *is oriented in a direct trajectory toward a 1-cm pulmonary nodule* →*. As necessary, the probe trajectory is corrected and aligned with the nodule prior to pleural entry. Minimizing the number of pleural punctures reduces the risk of procedure-related pneumothorax.* **(Right)** *After demonstrating an acceptable trajectory, the radiofrequency probe* → *is advanced into the lung parenchyma toward the nodule* →*, crossing the pleura only once.*



Radiofrequency Ablation: Lung Mass (Probe Positioned for RFA Treatment)

Radiofrequency Ablation: Lung Mass (NECT Immediately After Treatment)

(Left) *The radiofrequency probe* ➡ *is advanced into the nodule* → *with the tip just beyond the deep edge of the nodule. This RFA probe design requires connection to a pump (for internal cooling) and a generator, which is connected to grounding pads on the patient's skin.* **(Right)** *Immediately following the radiofrequency ablation, ground-glass opacities* ↪ *representing blood products surround the nodule. A halo (> 5 mm) completely encircling the nodule is a predictor of treatment success.*



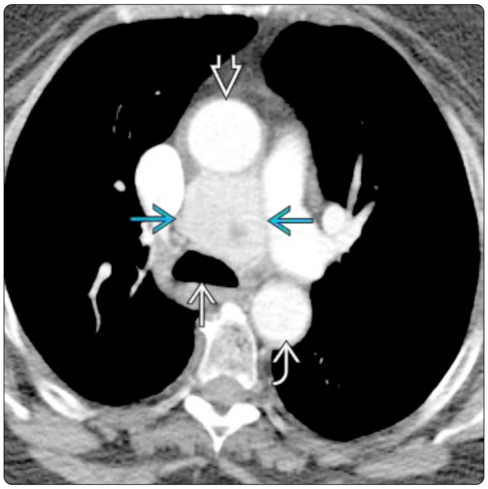
Radiofrequency Ablation: Lung Mass (3-Month Follow-Up)

Radiofrequency Ablation: Lung Mass (Late Posttreatment Imaging Findings)

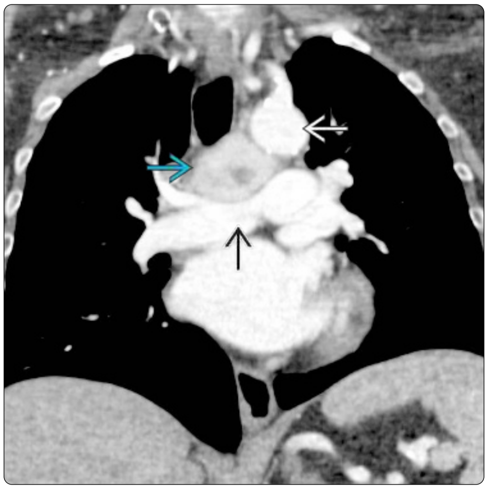
(Left) *An NECT was obtained 3 months after radiofrequency ablation of a right lower lobe nodule. The ablation zone* ➡ *contains a cavity* →*, which may involute over time.* **(Right)** *Benign pleural thickening* → *in the trajectory of the RFA probe may be seen on follow-up imaging and involute over serial examinations. Analyze the ablation zone* ↪ *for disease recurrence (e.g., peripheral nodular growth, enhancement, &/or new or increasing FDG avidity on PET).*

(Left) *An enhancing middle mediastinal mass ⇨ is anterior to the trachea ➡ and surrounded by vascular structures. The mass is in close proximity to both the ascending ➡ and descending ➡ thoracic aorta.* **(Right)** *Coronal CECT reconstruction shows the enhancing mass ⇨ in the middle mediastinum. The pulmonary arteries ⇨ course below the mass, and the transverse portion ➡ of the thoracic aortic arch is immediately adjacent.*

Embolization: Mediastinal Mass (Initial CECT Evaluation)

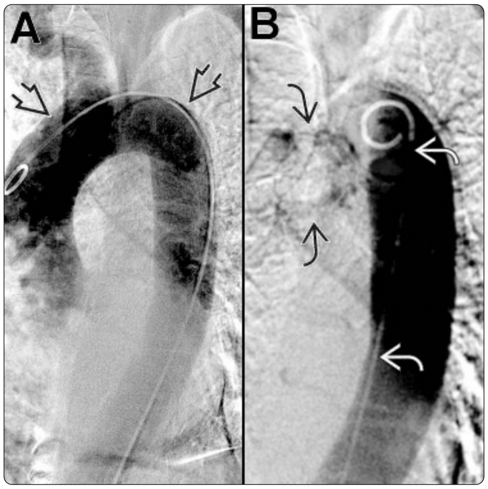


Embolization: Mediastinal Mass (Initial CECT Evaluation)

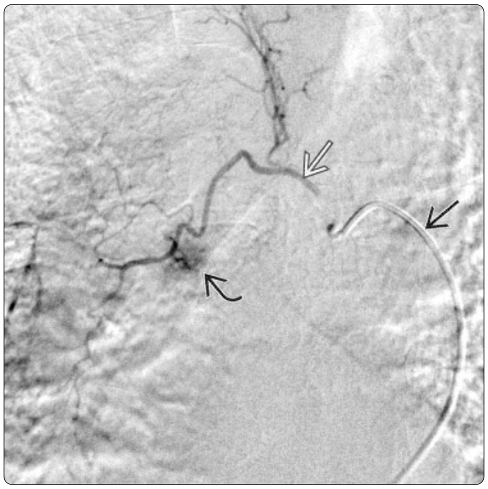


(Left) *Before surgical resection, transcatheter embolization was planned to devascularize the mass. (A) DSA of the thoracic aorta ⇨ was performed, given that the most likely arterial supply to the mass would arise here. (B) With the pigtail catheter ➡ in the descending aorta, a vascular blush ⇨ is seen medially.* **(Right)** *DSA via a Cobra catheter ⇨ in the right bronchial artery ➡ shows a small area of enhancement ⇨ in the region of the mass. This was felt to represent only part of the mass, given the aortography findings.*

Embolization: Mediastinal Mass (Thoracic DSA Aortography)

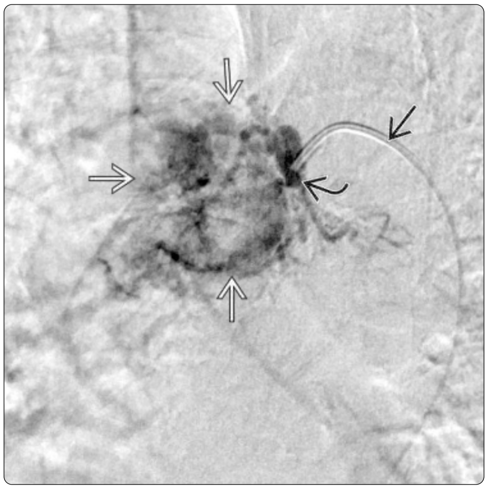


Embolization: Mediastinal Mass (Right Bronchial Artery DSA)

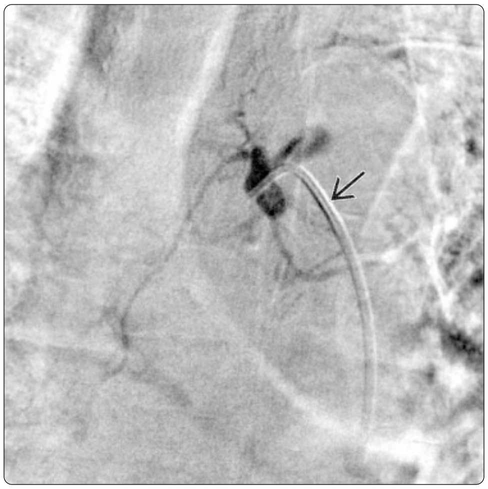


(Left) *An enlarged arterial branch ⇨ adjacent to the right bronchial artery was engaged with the Cobra catheter ⇨. DSA shows an intensely enhancing mass ➡ corresponding to the CT abnormality. A microcatheter could not be advanced more selectively.* **(Right)** *A slow embolization using particles suspended in dilute contrast was performed via the Cobra catheter ⇨ with fluoroscopic monitoring to avoid reflux and nontarget embolization. The postembolization DSA shows almost complete devascularization of the mass.*

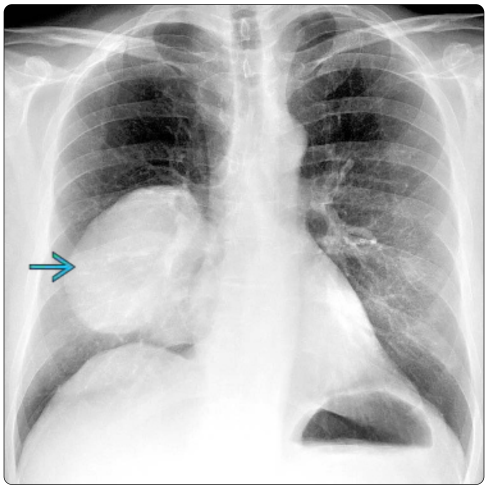
Embolization: Mediastinal Mass (DSA of Anomalous Arterial Branch)



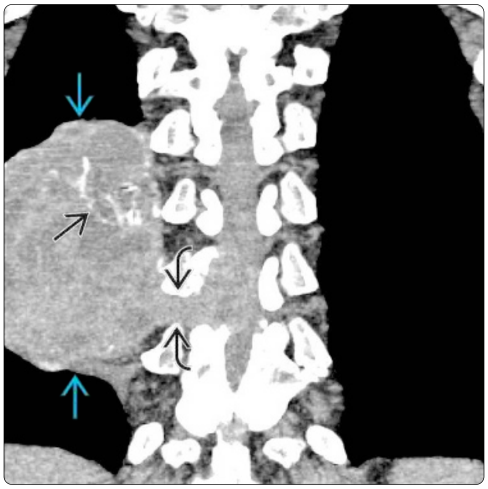
Embolization: Mediastinal Mass (Postembolization DSA)



Embolization: Giant Cell Tumor (Initial Radiographic Imaging)

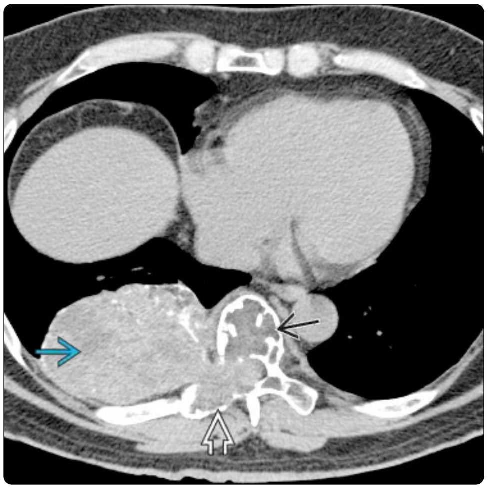


Embolization: Giant Cell Tumor (Initial CT Evaluation)

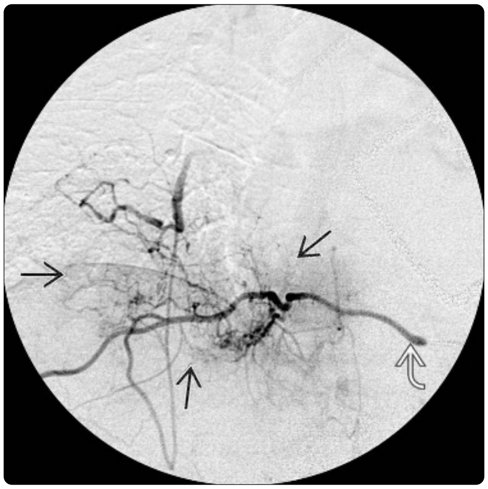


(Left) *A patient with back and pleuritic chest pain has a large mass → projecting in the medial aspect of the mid to lower right lung zone, posteriorly located on a lateral chest radiograph.* **(Right)** *The coronal NECT shows that the large mass → is contiguous with a right thoracic spinal neural foramen →. There are areas of dystrophic calcification → within the mass. The abnormality was felt to represent either an aneurysmal bone cyst or a giant cell tumor. Subsequent biopsy confirmed the latter diagnosis.*

Embolization: Giant Cell Tumor (Initial CT Evaluation)

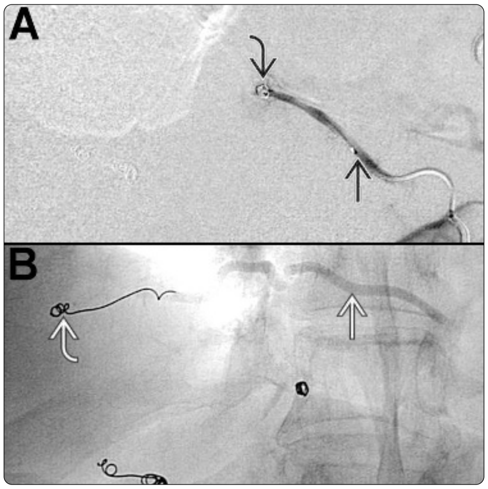


Embolization: Giant Cell Tumor (DSA Imaging)

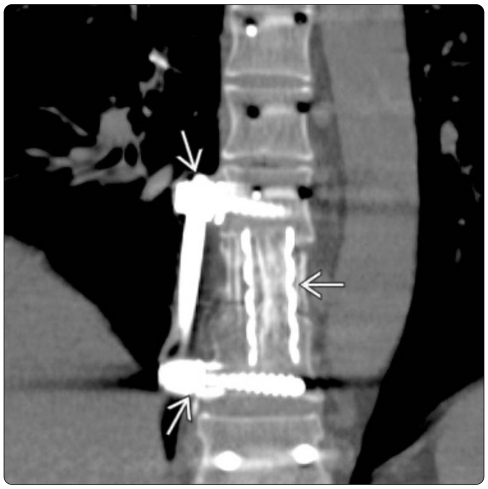


(Left) *An axial NECT shows the relationship between the mass → and the thoracic spine. This expansile mass has shell-like calcifications and an associated destructive process involving the contiguous thoracic vertebral body →, pedicle, and right transverse process →.* **(Right)** *Transcatheter embolization was requested in order to devascularize the mass prior to the planned surgical resection. A selective right intercostal artery → DSA shows tumor vascularity → corresponding to the distribution of the mass.*

Embolization: Giant Cell Tumor (Transcatheter Embolization)

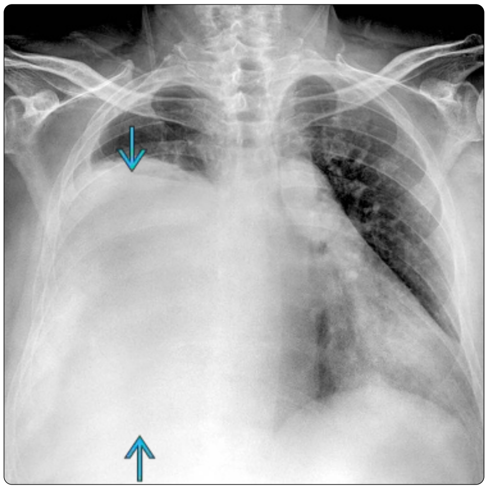


Embolization: Giant Cell Tumor (Postoperative CT Evaluation)

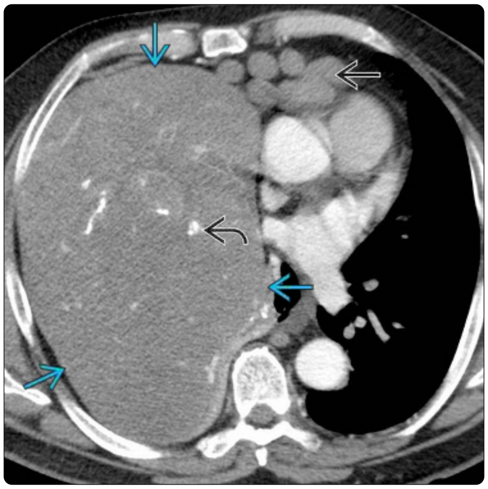


(Left) *(A) Via a coaxial microcatheter →, polyvinyl alcohol particles were injected to devascularize the mass, followed by coil embolization → of the feeding intercostal artery. (B) A more cephalad intercostal artery → was also particle and coil embolized → in a similar manner.* **(Right)** *The patient underwent surgical resection and spine stabilization surgery with very good hemostasis. Coronal NECT 1 year after resection shows the surgical hardware → and no obvious tumor mass.*

(Left) *A chest radiograph shows a large mass* ➔ *occupying 3/4 of the right hemithorax & displacing the mediastinal structures to the left in a man who had noted progressively worsening shortness of breath over the past 3 years.* **(Right)** *An axial CECT shows that the mass* ➔ *is solid & exhibits foci of enhancement* ↷ *after contrast administration. Enlarged draining veins* ➔ *are noted.*

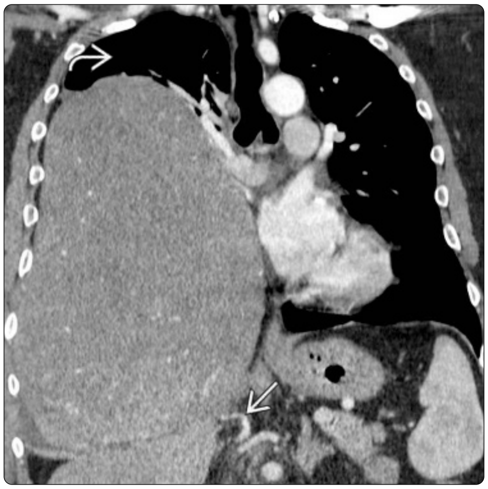


Embolization: Benign Lung Mass (Initial Chest Radiograph)

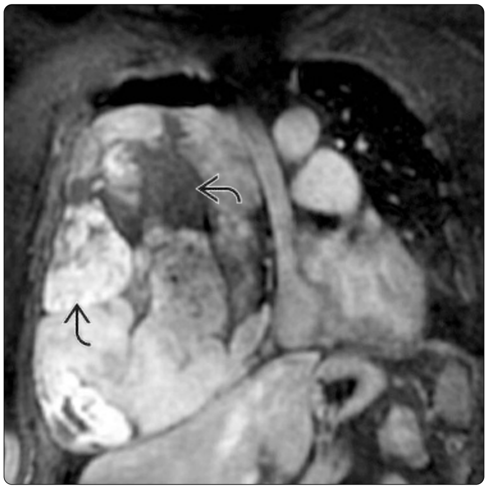


Embolization: Benign Lung Mass (Initial Axial CECT Evaluation)

(Left) *Coronal CECT shows that the only remaining aerated lung on the right* ↷ *is confined to the apex. A prominent vascular pedicle* ➔ *arising from the suprarenal abdominal aorta courses toward the mass. This was felt to represent a hypertrophied left inferior phrenic artery.* **(Right)** *Coronal T2WI MR shows that the mass has multiple lobulations* ↷ *& appears encapsulated. There is no obvious invasion of the bony thorax or adjacent soft tissues. Surgical resection of the mass was planned based on the imaging findings.*

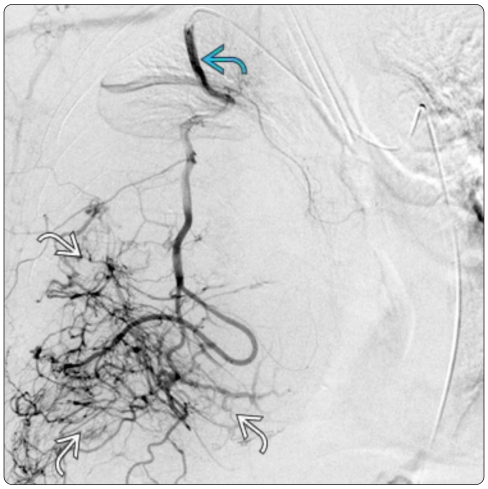


Embolization: Benign Lung Mass (Coronal CECT Reconstruction)

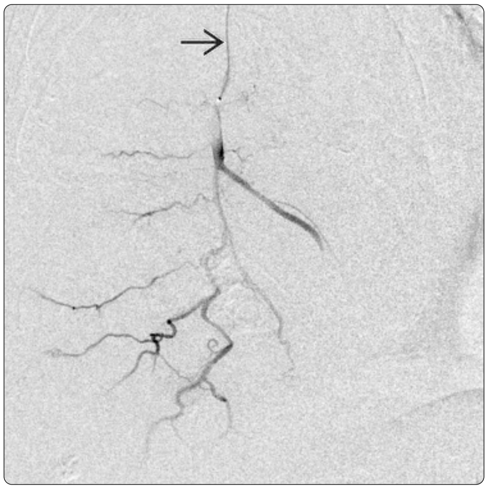


Embolization: Benign Lung Mass (Coronal MR Evaluation)

(Left) *Preoperative embolization of the arterial supply to the mass was requested in order to decrease intraoperative blood loss. Selective catheterization of the right internal mammary artery* ↷ *shows extensive tumor vascularity* ↷. **(Right)** *A coaxial microcatheter* ➔ *was advanced distally in the right internal mammary artery & was positioned proximal to the extensive network of tumor vascularity. Transcatheter embolization was performed using a Gelfoam slurry.*

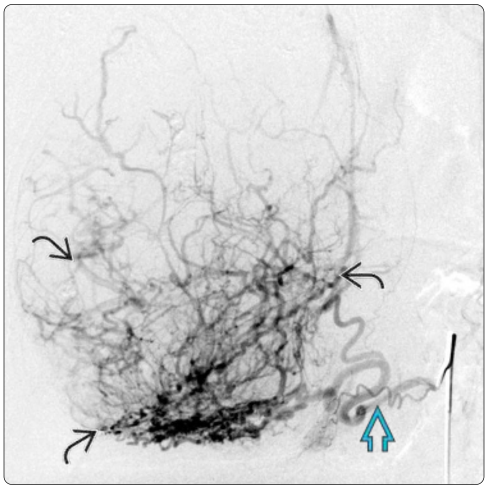


Embolization: Benign Lung Mass (Internal Mammary Artery DSA)

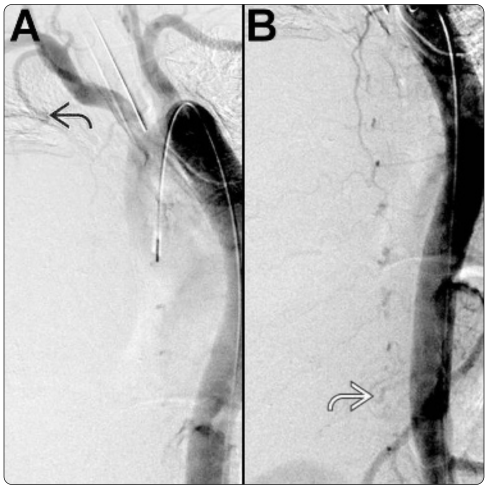


Embolization: Benign Lung Mass (Postembolization DSA)

Embolization: Benign Lung Mass (Inferior Phrenic Artery DSA)

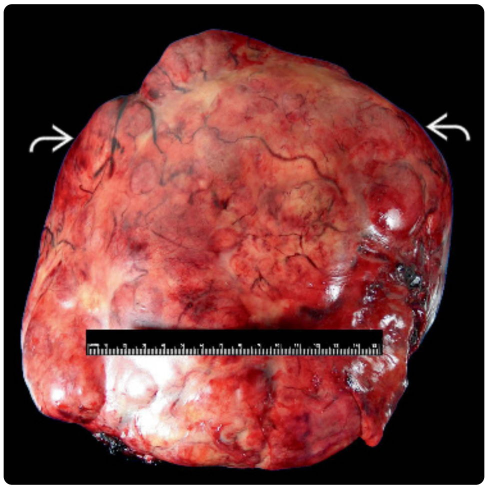


Embolization: Benign Lung Mass (Postembolization Aortic DSA)

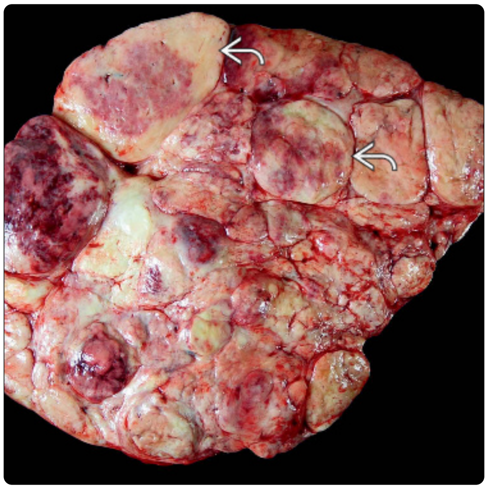


(Left) *DSA of the right inferior phrenic artery ⇨ shows the vessel to be hypertrophied and feeding the inferior aspect of the mass ↪. This was embolized with a Gelfoam slurry using the same coaxial technique that was employed in the right internal mammary artery.* **(Right)** *DSA of (A) the aortic arch & (B) descending thoracic aorta after Gelfoam embolization shows satisfactory devascularization of the mass. There is no filling of either the distal internal mammary ↪ or inferior phrenic ↪ arteries.*

Embolization: Benign Lung Mass (Gross Pathology Specimen)

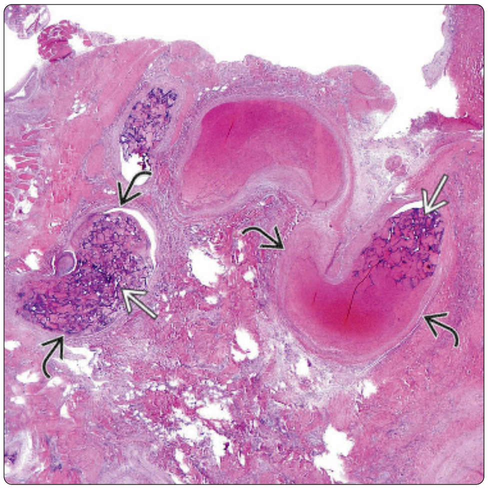


Embolization: Benign Lung Mass (Gross Pathology Specimen)

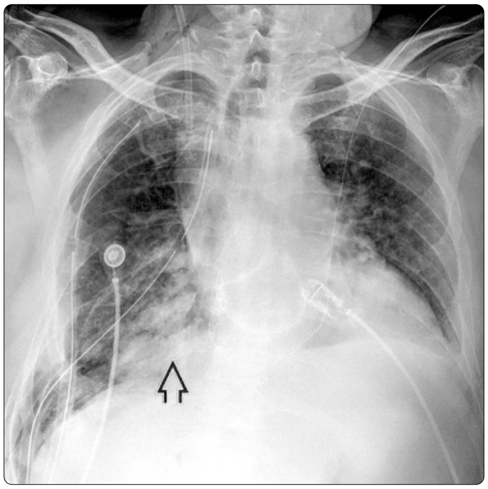


(Left) *After embolization the mass was successfully resected in its entirety, with minimal blood loss. Gross pathology specimen shows the well-encapsulated solitary fibrous tumor ↪, which is a rare mesenchymal tumor that typically arises from the visceral pleura & is often quite large. ~ 80% of these tumors are benign, & the treatment of choice is en bloc surgical resection.* **(Right)** *Gross pathology section of the solitary fibrous tumor shows the multiple lobulations ↪ that were evident on the preoperative MR.*

Embolization: Benign Lung Mass (Microscopic Pathology Specimen)



Embolization: Benign Lung Mass (Postoperative Chest Radiograph)



(Left) *Microscopic pathology section from the resected solitary fibrous tumor shows thrombosed vascular channels ↪ that contain Gelfoam particles ➔ from the transcatheter embolization.* **(Right)** *Postoperatively, the right lung is almost completely reexpanded with the exception of some residual basilar atelectasis ⇨. The mediastinal structures have resumed a midline position, and there is no evidence of any residual mass.*

Musculoskeletal Ablation and Embolization

KEY FACTS

PREPROCEDURE

- Indications
    - Treatment of osteoid osteoma
    - Palliation of musculoskeletal metastases
    - Adjunct to surgery
- Imaging
    - CT imaging guidance for ablation; fluoroscopic/DSA imaging guidance for embolization

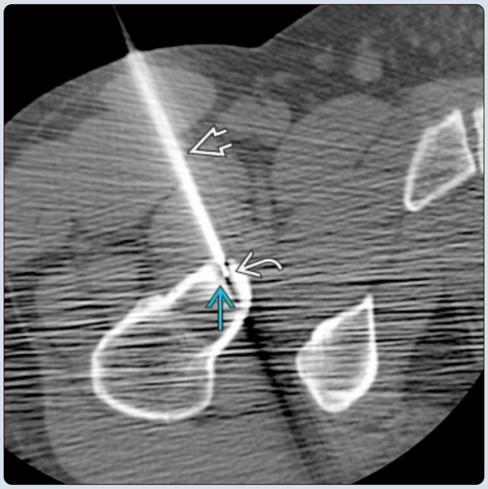
PROCEDURE

- **Ablation**
    - Prefer angle as perpendicular to cortex as possible
    - Prefer > 1-cm distance from neural structures
    - Coaxial bone drill system to enter bone
    - Overlapping ablations for lesion size > 1 cm
    - Osteoid osteoma
        - Radiofrequency ablation probe into nidus
        - Transient physiologic reaction may occur on entry
    - Metastases
        - Must avoid adjacent neurovascular structures
- **Embolization**
    - Obtain & analyze DSA images for embolization appropriateness & safety
    - Selectively catheterize dominant arterial branch feeding tumor; may use coaxial microcatheter
    - Determine optimal embolic agent based on tumor vascularity, potential shunting or non-target vasculature
    - Obtain confirmatory DSA from embolic delivery location
    - Embolize to stasis if possible

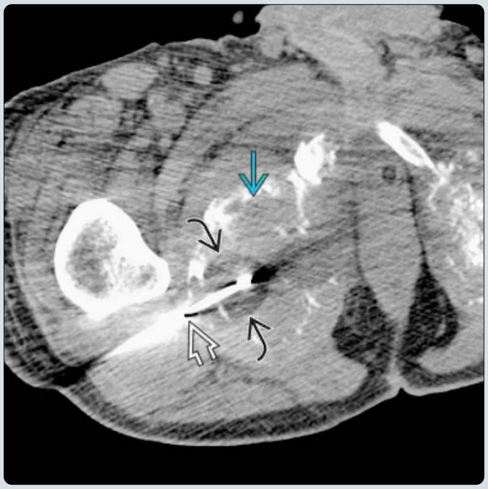
OUTCOMES

- Osteoid osteoma
    - Clinical success: No pain for 2 years
        - > 90% primary; > 80-90% in retreated lesions
- Metastases
    - Good clinical success of palliation with ablation, and with embolization if tumor is highly vascular
        - 60-80% improved or resolved pain

Radiofrequency Ablation: Osteoid Osteoma

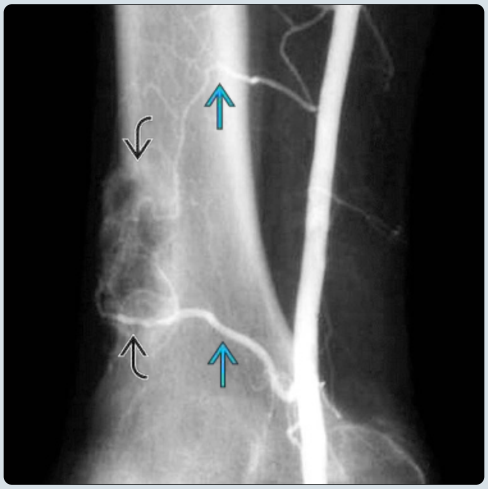


Cryoablation: Bladder Cancer Metastasis

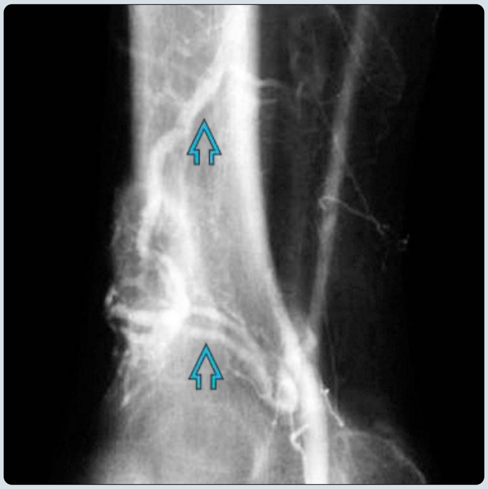


(Left) *Axial NECT of the proximal femur shows a radiofrequency probe* ⇨ *and outer cannula* ➡ *within a 1-cm cortical lucency* → *, which represents an osteoid osteoma. If needed, cortical entry may be achieved with a bone drill.* **(Right)** *Axial NECT during the initial freeze cycle of cryoablation demonstrates a cryoprobe* ➡ *within a painful destructive osseous metastasis* → *in a patient with bladder cancer. The hypodense ice ball* ⇨ *is well seen at the probe tip.*

Arteriovenous Shunting: Renal Cell Carcinoma Metastasis (Arterial Phase)



Arteriovenous Shunting: Renal Cell Carcinoma Metastasis (Venous Phase)



(Left) *A superficial femoral artery angiogram shows enlarged arterial branches* → *supplying a hypervascular, lytic destructive metastasis* ⇨ *invading the distal femur.* **(Right)** *Rapid filling of large draining veins* ⇨ *indicates the presence of arteriovenous shunting. This has implications for the choice of embolic agent used to treat the lesion due to the high risk of nontarget embolization from the embolic agent shunting through the fistula.*

TERMINOLOGY

Definitions

- **Osteoid osteoma**: Benign bone tumor arising from osteoblasts
    - Has central nidus of growing cells
        - Surrounded by hard shell of thickened bone
    - Most common in long bones (e.g., femur, tibia)
    - Most common in patients ages 4-25 years
        - Males affected 3x > females
    - Clinical presentation
        - Nighttime pain relieved by nonsteroidal antiinflammatory drugs

PREPROCEDURE

Indications

- **Ablation**
    - Osteoid osteoma
    - Musculoskeletal (MSK) metastatic disease
        - May be in conjunction with cementoplasty
        - Palliation
- **Embolization**
    - Primary/metastatic nonresectable MSK tumors
        - Effective only for vascular neoplasms
            - Avascular/hypovascular tumors unresponsive
        - In association with pathologic fracture
            - Adjunct to open reduction and internal fixation; better intraoperative hemostasis
        - Palliation

Contraindications

- **General**: Uncorrectable coagulopathy
- **Ablation**
    - Lack of safe access to lesion
        - Most hand/some spine lesions inaccessible
    - Proximity to structures at risk of thermal injury
        - Epiphyseal growth plate
        - Neurovascular structures
        - Skin/subcutaneous soft tissues
- **Embolization**
    - Contrast allergy
    - Renal insufficiency

Preprocedure Imaging

- **Osteoid osteoma**
    - CT
        - Somewhat variable appearance
        - Majority of lesions cortical in location
            - Circular lucent nidus/surrounding sclerosis
            - Nidus may have central mineralization (50%)
            - Nidus usually < 1.5 cm
            - Nidus seen better by CT than by MR
        - Subperiosteal/intramedullary lesions may have less sclerosis
    - MR
        - Nidus may demonstrate arterial enhancement
        - Surrounding bone marrow edema
- **MSK metastases**
    - Critical to assess adjacent neurovascular structures
    - Assess associated soft tissue component
        - Ablation may debulk soft tissue components
        - Embolization devascularizes soft tissue component

Getting Started

- Things to check
    - Procedure indications
    - Current medications
        - Any anticoagulant or antiplatelet agents
    - Electrophysiologist evaluation of pacemaker/defibrillator if radiofrequency ablation (RFA) planned
    - Laboratory parameters
        - Complete blood count
            - Platelet > 50,000/μL
        - Coagulation profile
            - International normalized ratio ≤ 1.5
            - Normal prothrombin time, partial thromboplastin time
        - Estimated glomerular filtration rate
- Medications
    - Anesthesia
        - 1% lidocaine local anesthetic
        - Many cases performed with anesthesiology team
            - MSK ablations often very painful
        - Procedural sedation may be considered
            - Fentanyl, midazolam typically used
    - Prophylactic antibiotics
        - Cefazolin (1 g)
- Equipment list
    - **Access through bone**
        - Coaxial drill system; e.g., Bonopty (AprioMed; Uppsala, Sweden)
            - Outer cannula with inner stylet
            - Coaxial hand drill

PROCEDURE

Patient Position/Location

- Best procedure approach
    - **Ablation**
        - Shortest distance to lesion preferred
            - e.g., supine/prone/decubitus/oblique positions
            - Access through opposite cortical surface may be required to avoid critical structures
        - Prefer angle as perpendicular to cortex as possible
            - Improves contact between needle and cortex
        - Prefer > 1-cm distance from neural structures
        - May need to overlap RFAs if lesion > 1 cm
        - Intraarticular lesions
            - Avoid transarticular approach when possible; reduces infection risk
            - Cartilage may be tolerant of adjacent heating
        - Spine
            - Avoid entry through neural foramen, facet joint
            - Prefer intact cortex adjacent to neural structures
    - **Embolization**: Transfemoral arterial access typically used

Equipment Preparation

- Hydrodissection
    - Consider nonionic contrast diluted in D_5W (e.g., 5-10 of mL iopamidol in 500 mL of D_5W)
        - Better margin delineation during hydrodissection

Procedure Steps

- **Ablation**
  - **General**
    - Perform preliminary CT; localize target
    - Sterilely prepare/drape skin
    - Administer 1% lidocaine to skin entry site
    - Nick skin with #11 blade
  - **Osteoid osteoma RFA**
    - Measure distance from skin to cortex on CT
      - Via skin "nick," advance cannula/inner stylet for distance measured on CT
    - Remove inner stylet
    - Perform CT scan; confirm position at cortex
    - Advance bone drill to within 1 mm of nidus
      - Perform intermittent CT to ascertain depth
    - Advance cannula over drill to nidus; remove drill
    - Obtain repeat CT to confirm position
    - If desired, may perform biopsy
      - Advance biopsy needle through cannula
      - Perform CT to confirm position
      - Obtain specimen; place in formalin
      - Remove biopsy needle
    - Advance RFA probe into nidus
      - Tachycardia, tachypnea, hypertension, and involuntary motion may occur on entry
      - Generally subsides during treatment
    - Perform CT to document active tip across nidus
    - Retract cannula > 1 cm
      - Prevents retrograde energy propagation along cannula; reduces risk of nontarget injury
    - Perform ablation treatment
      - System dependent
      - Typical ablation times may be at least 6 minutes
    - For lesion size > 1 cm
      - Reposition needle/cannula to obtain sufficient overlapping coverage
      - May require separate paths with coaxial bone drill set
    - Remove RFA probe and cannula
      - May administer local anesthetic via cannula prior to removal
    - Assess for complications with postprocedure CT
      - Generally unchanged appearance after ablation
  - **Ablation of metastases**
    - Must avoid adjacent neurovascular structures
    - Lesions in bone treated similar to osteoid osteoma
    - If treating soft tissue component of bone lesion
      - May consider cryoablation; ablation zone better delineated with ice ball
      - Consider hydrodissection of adjacent structures at risk of thermal injury
    - Weight-bearing structures (e.g., acetabulum) may benefit from cementoplasty
- **Embolization**
  - Obtain arterial access
  - Introduce access sheath/selective catheter
  - Catheterize artery most likely supplying tumor
  - Obtain/analyze DSA images
    - Assess for embolization appropriateness/safety
    - Determine appropriate/optimal embolic agent
      - Particles may be contraindicated with significant arteriovenous shunting
  - Selectively catheterize dominant arterial branch feeding tumor; may use coaxial microcatheter
    - Obtain DSA; proceed with embolization

POST PROCEDURE

Things to Do

- Follow-up imaging of osteoid osteoma not required
  - Obtain CT if patient reports continued symptoms
  - May be amenable to retreatment

Things to Avoid

- Strenuous activity, especially following treatment of lesions in weight-bearing structures

Post Procedure Imaging

- Imaging of treated osteoid osteoma
  - Not required after clinically successful RFA of osteoid osteoma
  - Within 2 years, see sclerosis of nidus; generally indistinguishable from surrounding bone
  - MR ultimately shows marrow edema resolution

OUTCOMES

Problems

- Osteoid osteoma: Pain may increase over 24-48 hours
  - Discharge with oral analgesics
- Metastases: Pain flare first 48 hours
  - Higher risk in pelvis lesions
  - May require admission after procedure

Complications

- Most feared complication(s)
  - Nerve injury (ablation)
    - Meticulous pretreatment planning important
  - Vascular injury (ablation/embolization)
- Immediate/periprocedural complication(s)
  - Skin burn (ablation)
    - Overlying treatment site
    - At grounding pad site
      - Shave skin/ensure good contact to reduce risk
  - Hemorrhage (ablation/embolization)
  - Pain (ablation/embolization)
  - Nontarget embolization
- Delayed complication(s)
  - Infection

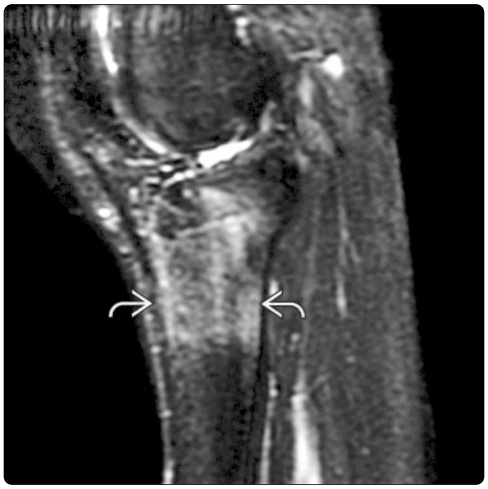
Expected Outcomes

- Osteoid osteoma
  - Clinical success: No pain for 2 years
    - > 90% primary success
    - > 80-90% clinical success in retreated lesions
- Metastases: 60-80% improved or resolved pain

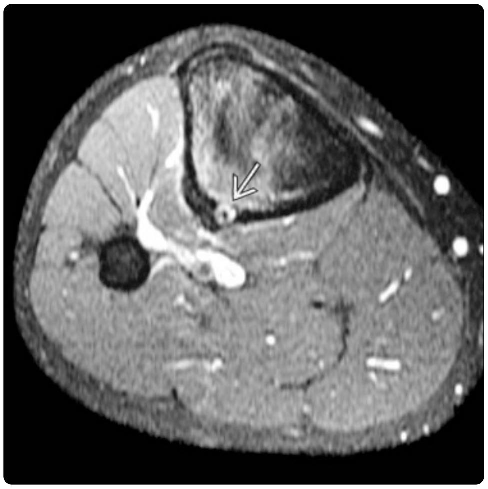
SELECTED REFERENCES

1. Nazario J et al: Thermal ablation of painful bone metastases. Tech Vasc Interv Radiol. 14(3):150-9, 2011

Ablation: Osteoid Osteoma (Initial MR)

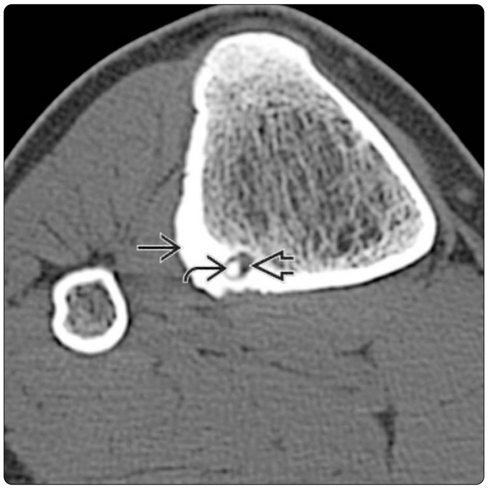


Ablation: Osteoid Osteoma (Initial MR)

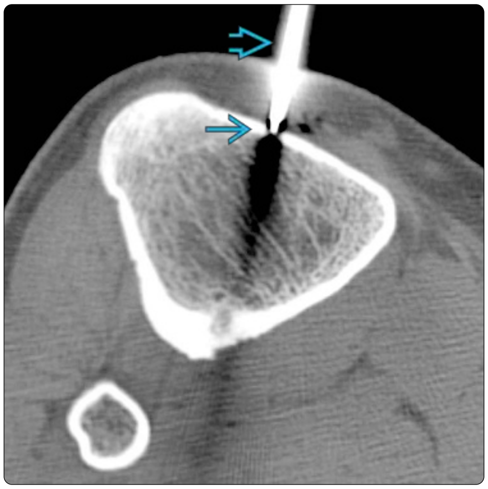


(Left) *Sagittal STIR MR of the proximal tibia demonstrates increased signal ↪, reflecting bone marrow edema. This is a common MR finding in osteoid osteoma.* **(Right)** *Enhancement ➡ within the cortical nidus is a typical finding in osteoid osteoma. Clinically, patients with osteoid osteoma experience pain that is worse at night and may be relieved with nonsteroidal antiinflammatory drugs. Because the symptomatology may last for many years, percutaneous ablation is a valuable and effective treatment option.*

Ablation: Osteoid Osteoma (Initial CT)

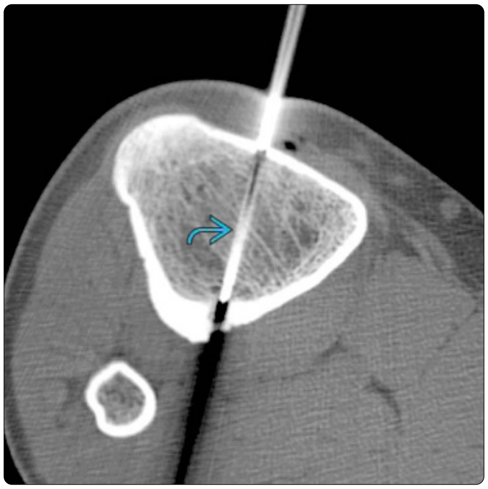


Ablation: Osteoid Osteoma (Approach for Biopsy and Ablation)

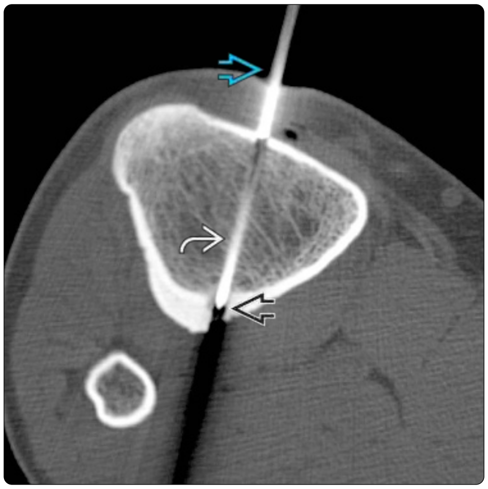


(Left) *The radiolucent nidus ⇨ may contain a central focus of mineralization ↪. The nidus is surrounded by thickened sclerotic bone →. CT may be more sensitive for detection of the nidus than is MR.* **(Right)** *The cannula ⇨ of a coaxial biopsy system is advanced through the overlying soft tissues until the tip → reaches the cortex. A perpendicular approach to the cortex is desired for stability.*

Ablation: Osteoid Osteoma (Biopsy Prior to Ablation)



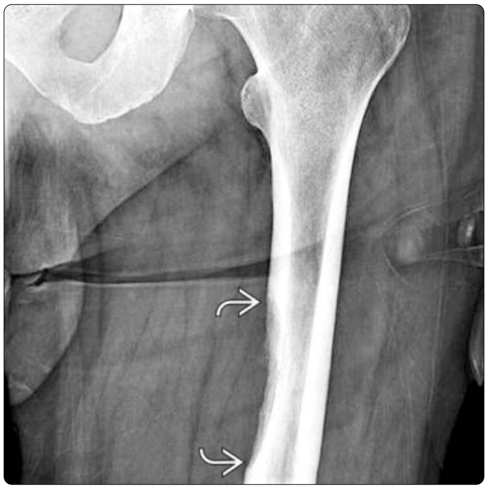
Ablation: Osteoid Osteoma (Radiofrequency Probe in Position)



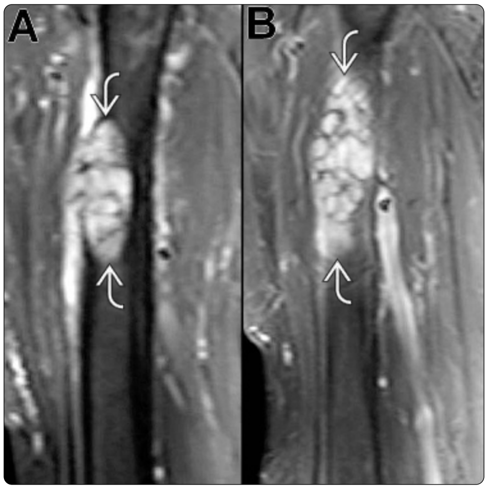
(Left) *A hand drill ↪ has been bored through the tibia until the tip is within 1 mm of the anterior margin of the nidus. After removing the drill from the cannula, a biopsy needle is advanced into the nidus and a specimen obtained.* **(Right)** *After biopsy, a single-needle-type RFA probe ↪ is advanced through the cannula ⇨ into the nidus ⇨. The probe and grounding pads are connected to the generator, and the automatic ablation program is activated. In this case, an anterior approach was used in order to avoid the posterior neurovascular structures.*

(Left) *Anteroposterior radiograph obtained in a patient with a prior history of renal cell carcinoma and the new onset of proximal left thigh pain shows a destructive lesion ➦ involving the medial cortex of the proximal femur.* **(Right)** *A coronal T2WI MR shows (A) that an expansile soft tissue mass ➦ is the cause of the destructive osseous lesion that was noted on the plain radiograph. (B) A contiguous, slightly more posterior coronal MR demonstrates more of the extent of the soft tissue mass invading the medial femur.*

Embolization: Renal Cell Metastasis (Initial Radiographic Imaging)

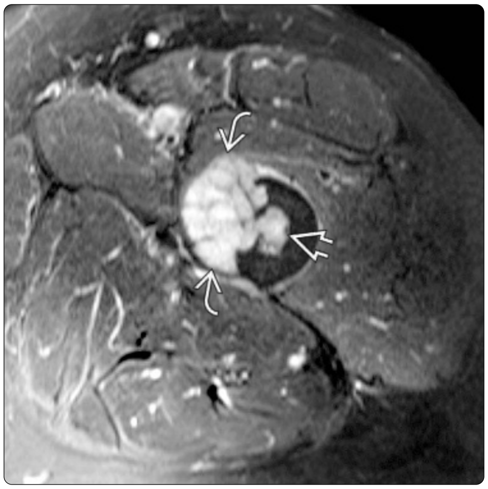


Embolization: Renal Cell Metastasis (MR)

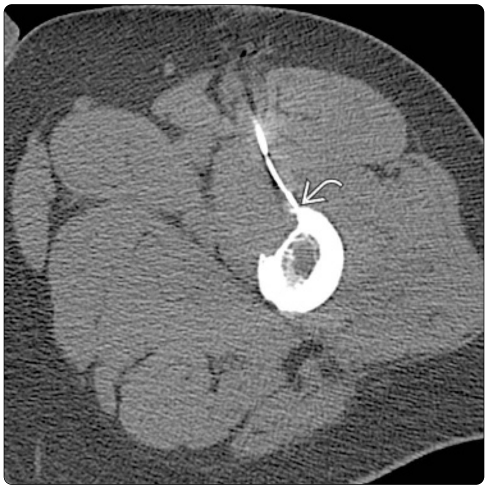


(Left) *Axial T2WI MR shows that the soft tissue mass ➦ has destroyed ~ 1/3 of the diameter of the femoral diaphysis. Additionally, it has invaded centrally into the bone marrow cavity ⇒. The patient is at risk for developing a pathologic fracture.* **(Right)** *Given the history of renal cell carcinoma, a metastasis was the most likely etiology for the destructive lesion. Histologic diagnosis was requested, as this was a solitary lesion. NECT obtained during guidance for biopsy shows the needle tip ➦ in good position.*

Embolization: Renal Cell Metastasis (MR)

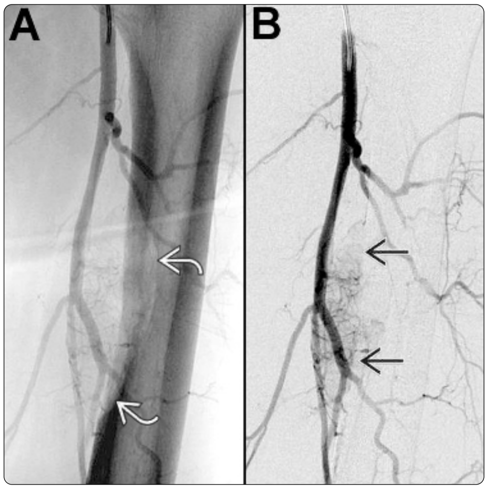


Embolization: Renal Cell Metastasis (CT-Guided Bone Biopsy)

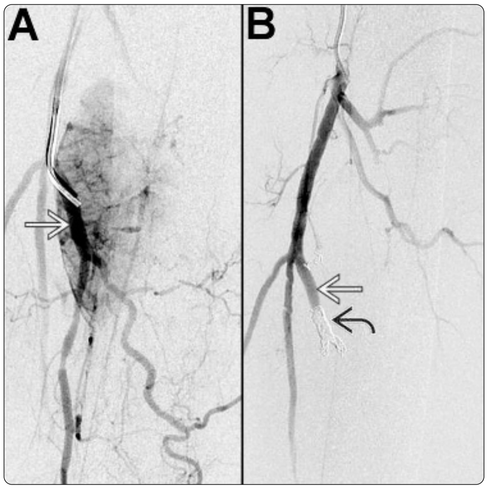


(Left) *(A) Native and (B) subtracted DSA images show the destructive femoral lesion ➦ and hypervascularity ⇨ to the tumor, which was biopsy-proven renal cell carcinoma. Branches of the profunda femoral artery supply the mass.* **(Right)** *(A) The arterial feeding branch ➡ was catheterized and DSA performed, excluding arteriovenous shunting. (B) Particles were 1st delivered into distal arteries supplying the mass, followed by coil embolization ↪ of the branch artery arising from the profunda femoris.*

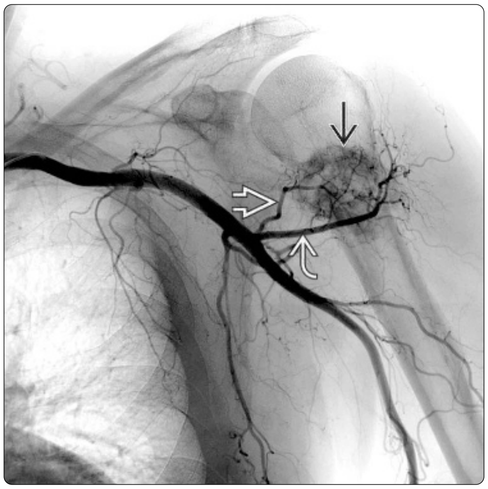
Embolization: Renal Cell Metastasis (Initial DSA Evaluation)



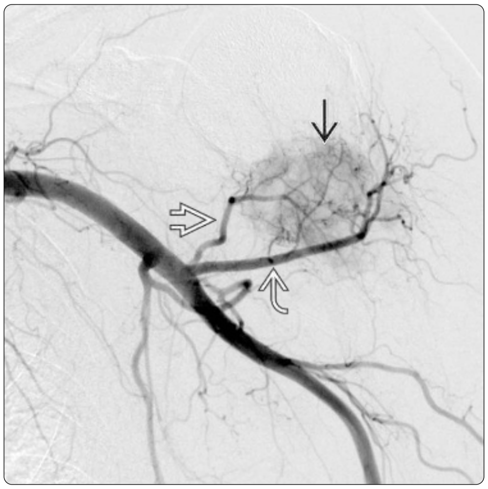
Embolization: Renal Cell Metastasis (Coil and Particle Embolization)



Embolization: Thyroid Carcinoma Metastasis (Initial Arteriogram)

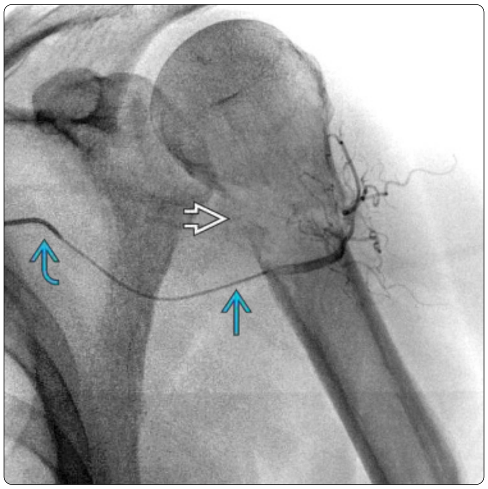


Embolization: Thyroid Carcinoma Metastasis (Initial DSA)

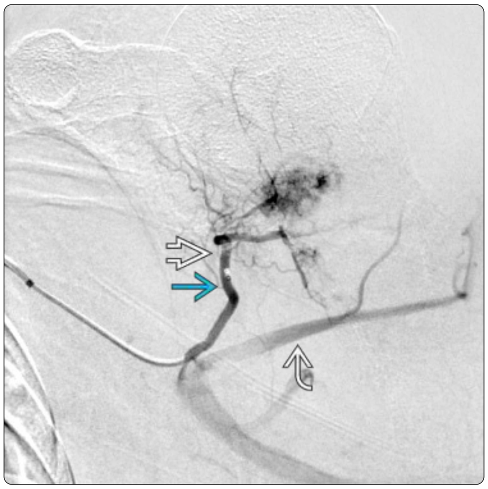


(Left) *A native DSA shows a hypervascular mass* → *in the proximal left humerus, supplied predominantly by the anterior* ⇨ *and posterior* ↪ *circumflex humeral arteries. Prior CT-guided biopsy confirmed a diagnosis of metastatic medullary thyroid carcinoma.* **(Right)** *The same arteriogram with digital subtraction and magnification better displays the anterior* ⇨ *and posterior* ↪ *circumflex humeral arteries supplying the hypervascular mass* →.

Embolization: Thyroid Carcinoma Metastasis (Posterior Circumflex Particle Embolization)

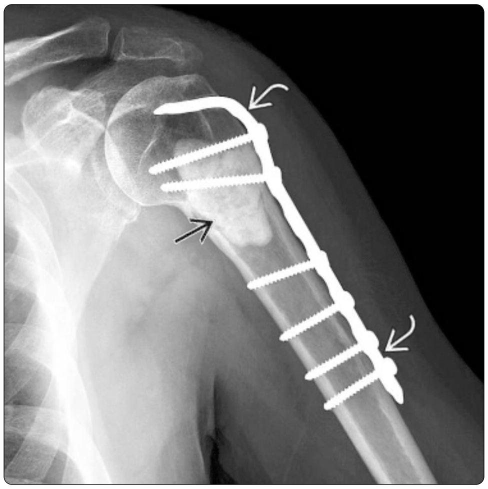


Embolization: Thyroid Carcinoma Metastasis (Anterior Circumflex Particle Embolization)

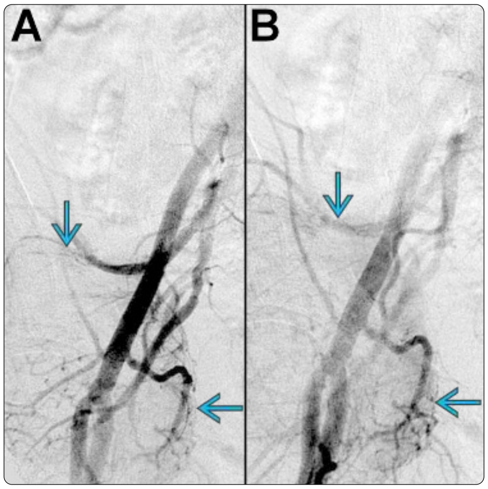


(Left) *A microcatheter* → *was introduced coaxially via the 5-Fr catheter* ↪ *in the axillary artery into the posterior circumflex humeral artery. Embolization with 300- to 500-µm particles was performed with marked reduction of the tumor vascularity. There is a pathologic fracture* ⇨ *noted.* **(Right)** *The microcatheter* → *was withdrawn from the posterior circumflex humeral artery* ↪ *and then advanced over a wire into the anterior circumflex humeral artery* ⇨ *where further particle embolization was performed.*

Embolization: Thyroid Carcinoma Metastasis (ORIF of Pathologic Fracture)



Embolization: Thyroid Carcinoma Metastasis (Acetabular Metastasis)



(Left) *The patient underwent open reduction and internal fixation (ORIF) of the pathologic fracture with a combination of orthopedic hardware* ↪ *and bone cement* →*. Intraoperative hemostasis was excellent due to the transcatheter tumor embolization.* **(Right)** *Two years later, the patient had new onset of right hip pain due to a new right acetabular metastasis. DSAs in (A) the early arterial (B) and late arterial phases show the large hypervascular mass* →.

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SECTION 5

Neuroradiology Procedures

Intracranial Revascularization

Stroke Therapy 638

Carotid or Vertebral Angioplasty/Stenting 646

Spinal Interventions

Lumbar Puncture, Myelogram, and CSF Leaks 654

Vertebral Augmentation and Sacroplasty 658

Stroke Therapy

KEY FACTS

TERMINOLOGY

- **Stroke**: Rapidly developing loss of brain function(s) due to disturbance in blood supply to brain
- **Core infarct**: Central area of severe ischemia/evolving infarction; unlikely to respond to treatment
- **Ischemic penumbra**: Surrounding ischemic tissue rim between normally perfused brain and evolving infarction

PREPROCEDURE

- Noncontrast head CT: Exclude hemorrhage, evaluate extent of core infarct [Alberta Stroke Program Early CT Score (ASPECTS)]
- CTA head/neck ± CT head perfusion: Localize arterial occlusion, detection of penumbra
- Thrombectomy inclusion criteria
    - Large vessel occlusion; symptoms ≤ 6-8 hours
    - Significant neurological symptoms [National Institute of Health Stroke Scale (NIHSS) > 4]
    - Minimal ischemic burden (ASPECTS ≥ 6)
    - Salvageable tissue by perfusion imaging
- Absolute contraindication: Hemorrhage/well-established acute infarct involving > 1/3 of affected vascular territory

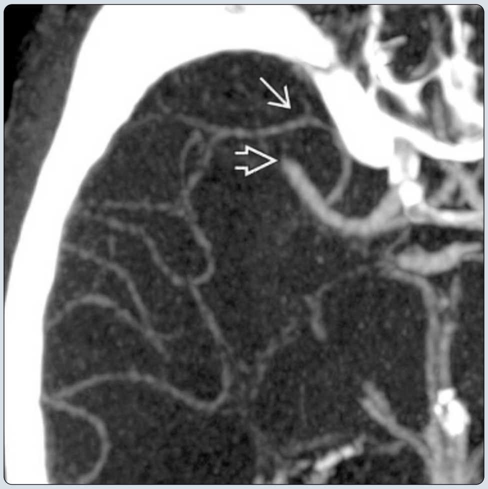
PROCEDURE

- Thrombectomy with stent retriever
    - Placement of balloon guide catheter in internal carotid artery (ICA) or subclavian artery
    - Deploy stent retriever device across thrombus, wait 5 min
    - Balloon occlusion of ICA/subclavian while retracting device and thrombus into guide catheter
- Aspiration thrombectomy, angioplasty ± stenting, intraarterial thrombolysis as backup in select cases

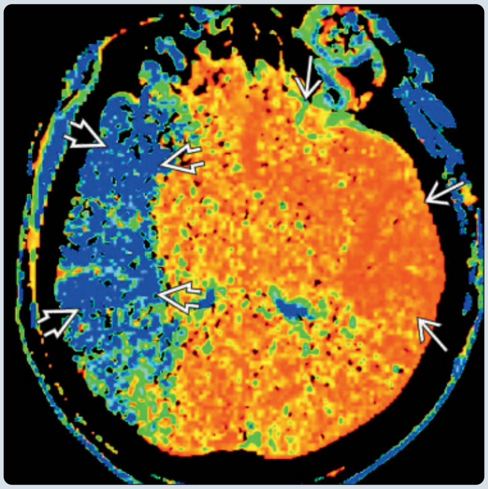
POST PROCEDURE

- 72-93% successful recanalization
- 51-60% good clinical outcome
- 3.6% intracerebral hemorrhage

Acute Stroke Intervention: Initial CTA

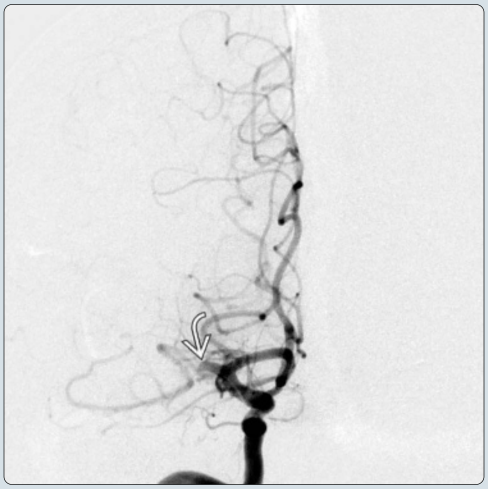


Acute Stroke Intervention: CT Perfusion

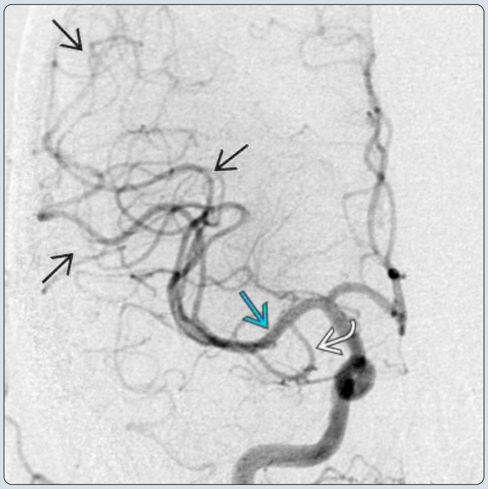


(Left) *Reformatted CTA shows occlusion of the right MCA, M1 segment ⇨. The anterior temporal branch of the right MCA remains patent →. The appearance is typical of an embolic occlusion.* **(Right)** *CT brain perfusion shows a prolonged mean transit time (MTT) in the right MCA territory ⇨ compared to the left side → due to the MCA occlusion. MTT, which measures average blood transit time through a given region of the brain, is a sensitive parameter for restricted perfusion, as seen with embolic occlusion.*

Acute Stroke Intervention: Initial Cerebral Angiography



Acute Stroke Intervention: Completion Arteriogram



(Left) *Right internal carotid DSA shows occlusion of the right MCA, M1 segment ↪, corresponding to the CTA. Acute stroke therapy with mechanical thrombectomy was then performed.* **(Right)** *Right internal carotid DSA following mechanical thrombectomy shows a patent MCA → and distal branches →, which were previously nonperfused. The anterior temporal branch ↪ remains patent and is again seen arising from the mid M1 segment.*

TERMINOLOGY

Definitions

- **Stroke**: Acute loss of brain function(s) due to disturbance in blood supply to brain
  - Ischemic stroke: Embolic or thrombotic occlusion of arterial supply to brain (80% of strokes)
    - 3 major clinical ischemic stroke subtypes
      - ☐ Large artery/atherosclerotic strokes (40-50%)
      - ☐ Cardioembolic disease (20-25%)
      - ☐ Lacunar infarction (20-30%)
  - Hemorrhagic stroke: Rupture/bleeding from brain blood vessel (15% of strokes)
  - Nontraumatic subarachnoid hemorrhage (5%)
  - Vasculitis
  - Venous infarction (< 1%)
- **Core infarct**: Central area of severe ischemia/evolving infarction; unlikely to respond to treatment
  - Severely reduced to almost nonexistent blood flow
  - Inadequate supply of oxygen and glucose
  - Neuronal and glial necrosis
    - Irreversible damage; no response to reperfusion
- **Ischemic penumbra**: Surrounding rim of ischemic tissue between normally perfused tissue and area of evolving infarction
  - Parenchymal tissue at risk of eventual infarction
    - Dependent upon collateral perfusion
    - Collateral circulation inadequate to maintain neuronal oxygen/glucose demand indefinitely
  - May remain viable for several hours
  - Target of acute stroke intervention
- **Endovascular therapy (ET)**: New standard of care for acute ischemic stroke with emergent large vessel occlusion (ELVO)
  - Potential reperfusion techniques
    - Intravenous thrombolysis [IV tissue plasminogen activator (tPA)]
    - Mechanical thrombectomy (stent retriever, aspiration catheter)
    - Balloon angioplasty/stenting
    - Intraarterial thrombolysis
- **Stroke-related scales/grades**
  - **National Institutes of Health Stroke Scale (NIHSS)**
    - Clinical assessment tool used to quantify neurologic impairment caused by acute stroke
    - Predictor of short- and long-term outcome

PREPROCEDURE

Indications

- **IV tPA**
  - Patients with acute neurologic deficit expected to result in long-term disability
  - NECT shows no hemorrhage and no large infarct
  - Clearly defined onset time (last known well time) and presentation within 3-4.5 hours of symptom onset
  - No contraindication to tPA
- **ET**
  - Patients with large vessel occlusions documented by CTA, DSA, or MRA
    - Anterior circulation: When revascularization is feasible within 6-8 hours of symptom onset
    - Posterior circulation: Time window undefined, but within ≤ 12-24 hours of symptom onset
  - NIHSS > 4, exceptions for cases of isolated aphasia or hemianopsia
  - No large infarct on NECT [Alberta Stroke Program Early CT Score (ASPECTS) ≥ 6]
  - Significant area of salvageable tissue seen on perfusion imaging

Contraindications

- **Absolute contraindications to ET**
  - Intracranial hemorrhage (ICH)
  - Established acute infarct involving > 1/3 of affected vascular territory
    - ASPECTS ≤ 5 has greater risk of hemorrhage
  - CNS lesion with elevated likelihood of hemorrhage during revascularization
    - Abscess
    - Aneurysm
    - Brain tumor
  - Established bacterial endocarditis
- **Relative contraindications (general)**
  - Mild or rapidly improving deficits
  - Stroke or ICH in same territory within 3 months
  - Suspected bacterial endocarditis
  - Life expectancy < 1 year from other causes

Preprocedure Imaging

- **Noncontrast head CT**
  - Exclude ICH
  - Look for established infarct (frank hypodensity)
  - Calculate ASPECT score
    - 10-point grading scale for severity of MCA stroke on NECT
    - 1 point deducted from initial score of 10 for every region involved
      - ☐ Caudate, putamen, internal capsule, insular cortex, and 6 regions of MCA cortex (3 superior, 3 inferior)
- **CTA head and neck**
  - Localize site of arterial occlusion(s) or stenosis
  - Evaluate for vascular tortuosity or variant vascular anatomy
- **CT head perfusion**
  - Mean transit time
    - Average blood transit time through a brain region
    - Highly sensitive parameter for detection of brain tissue oligemia
  - Time to peak/TMax
    - Time to peak density of contrast through brain region
    - Highly sensitive parameter for detection of brain tissue oligemia
  - Cerebral blood flow (CBF)
    - Blood volume moving through brain
    - Reasonable marker for extent of impending infarction
  - Cerebral blood volume (CBV)
    - Total blood volume in given unit volume of brain
    - Reasonable marker for core infarct
    - Larger core infarct is marker for poor outcome
  - CBF/CBV mismatch defines extent of penumbra

- **MR diffusion (DWI) and MR perfusion (PWI) imaging**
    - Added screening time and scan time limits usefulness in emergent stroke evaluation
    - DWI most reliable estimate of core infarct
    - DWI/PWI mismatch defines extent of penumbra
    - Helpful in basilar distribution stroke where CT perfusion is less accurate

Getting Started

- Things to check
    - Focused clinical history/physical examination
        - Pinpoint time of onset of stroke symptoms
            - If symptoms present upon awakening, consider onset as when patient was last symptom-free
        - Obtain NIHSS
            - Assess thrombolysis inclusion vs. exclusion
        - Exclude conditions that mimic stroke (e.g., seizure, toxic/metabolic syndromes, hypoglycemia, tumor)
    - Allergies to sedatives, contrast
    - Current medications, including any anticoagulants
    - Laboratory parameters
        - Electrolytes, glomerular filtration rate (eGFR)
        - CBC
            - Platelet count > 50,000/μL
        - Coagulation profile
    - Consent for procedure
        - Discuss risk of hemorrhagic stroke, vascular injury, allergic reaction, renal failure, access site hematoma
- Medications
    - IV tPA
        - Infuse 0.9 mg/kg (maximum 90 mg) over 60 minutes; bolus first 10% of dose over 1 minute
        - Maintain SBP < 180 mm Hg; DBP < 105 mm Hg
        - If new severe headache, acute hypertension, or nausea, obtain head CT
        - Acceptable to stop infusion to perform thrombectomy or continue infusion during thrombectomy
        - Patient management after thrombolysis
            - No anticoagulation/antiplatelet therapy for 24 hours
    - Procedural sedation
        - Usually performed without sedation or with light sedation using fentanyl and midazolam if needed
        - Use of general anesthesia is associated with worse neurological outcomes
        - Posterior circulation stroke may require airway support
- Equipment list
    - Sheaths/guide catheters
        - Various proprietary designs
            - Femoral arterial sheath
            - Balloon guide catheter for flow arrest during withdrawal of thrombus
    - Guidewires
        - Hydrophilic 0.035" or 0.038" guidewire
        - Microwire for use with appropriate microcatheter
    - Equipment for mechanical thrombectomy
        - Stent retrievers for ensnaring and withdrawing thrombus
        - Reperfusion catheters for local aspiration of thrombus
        - May do combined stent retriever, local aspiration, and balloon guide technique
    - Angioplasty balloons for concomitant angioplasty and carotid stenting
        - Rapid-exchange or monorail systems preferred

PROCEDURE

Patient Position/Location

- Supine position, biplane angiography suite

Procedure Steps

- **Diagnostic angiogram**
    - Sterilely prepare/drape skin of access site
        - Transfemoral access site preferred, transbrachial or transcarotid access if needed
    - Conscious sedation if necessary
    - Obtain femoral arterial access
        - Place femoral artery access sheath
            - 4- to 6-Fr (for diagnostic angiogram)
            - 8-Fr (for thrombectomy with balloon guide)
        - Select desired carotid/vertebral artery with Glidewire/diagnostic catheter
    - Use diagnostic catheter to obtain DSA images
        - Carotid/vertebral DSA: Evaluates collateral circulation/filling of vessels distal to occlusion
            - Include cervical and cranial views
        - Obtain magnified images of target vessel(s), document vascular occlusion
- **Thrombectomy with stent retriever device**
    - Useful for occlusions out to M3 segment in MCA or P1 segment in posterior cerebral artery
    - Advance balloon guide catheter over wire into internal carotid artery (ICA)
    - Navigate microwire/microcatheter into occluded segment
        - Pass occlusion site with microwire/microcatheter
        - Obtain DSA; verify position of microcatheter tip within vessel, distal to thrombus
    - Advance stent retriever device and deploy across thrombus
    - Wait 5 minutes for device to interact with thrombus
    - Inflate balloon at guide catheter tip within ICA for temporary occlusion
    - Aspirate lumen of balloon guide catheter
        - Check for thrombus within device or aspirate
        - Check Touhy valve for thrombus
    - Deflate balloon
    - Verify backflow of blood out from balloon guide to ensure thrombus not trapped within guide catheter
    - Obtain DSA run through guide catheter to evaluate for residual thrombus or distal emboli
        - Assess thrombolysis in cerebral ischemia (TICI) score
        - If needed, reload stent retriever device for additional passes
        - Average 1.6 passes required
    - Atherosclerotic stenosis or dissection can be treated with angioplasty/stenting in select cases
    - Cervical run of ICA to ensure no spasm or dissection from guide catheter

  - Pull guide catheter to iliac artery; pelvic run to ensure proper placement of sheath for hemostatic closure device
- **Thrombectomy with aspiration catheter**
  - Most useful for occlusion within large straight segments, such as paraclinoid ICA, M1, or basilar
  - Position long 6-Fr (or larger) sheath in carotid or subclavian artery
  - Choose reperfusion catheter size based on occluded vessel diameter
  - Advance reperfusion catheter into target vessel over microcatheter/microwire
  - Confirm catheter position with DSA imaging
  - Engage proximal face of thrombus with reperfusion catheter and aspirate by syringe or aspiration pump
  - Follow results with DSA angiography
- **Thrombectomy combining stent retriever and local aspiration**
  - Useful when balloon guide catheter placement in ICA not possible or contraindicated
  - Position long 6-Fr sheath or balloon guide catheter in carotid or subclavian artery
  - Choose reperfusion catheter based on occluded artery diameter
  - Navigate reperfusion catheter over microcatheter and microwire to target artery
  - Pass occlusion with microcatheter and deploy stent retriever device across thrombus
  - While reperfusion catheter is being aspirated, withdraw stent retrieval device into catheter
  - Search for thrombus ensnared in device or aspirate
  - Repeat if necessary
- **Intracranial angioplasty ± stenting** (not FDA approved for acute stroke)
  - Use if recanalization attempts unsuccessful due to underlying stenosis
  - Angioplasty balloon size based on occluded vessel
    - Use balloon slightly smaller than vessel caliber
    - Recommend noncompliant angioplasty balloon
    - Advance balloon into occluded segment, inflate
  - Perform follow-up DSA
- **Associated cervical carotid stenosis/occlusion**
  - Acute stenting of high-grade stenosis/occlusion may be required to achieve access for thrombectomy
  - Probing stump of occluded ICA often reveals residual lumen in acute stroke
  - Advance microcatheter to distal ICA
  - Angiogram through microcatheter will demonstrate thrombus burden within ICA
  - Place exchange wire in distal ICA to facilitate placement of distal embolic protection filter device, if possible
  - Occluded ICA may have to initially be predilated with very small balloon
  - Vagus nerve induced bradycardia may be profound
    - Premedicate with atropine or glycopyrrolate
  - Stent retriever use after stenting
    - Requires placement of balloon guide catheter distal to stent or use of reperfusion catheter
      - Avoid retracting stent retriever through ICA stent
    - In setting of significant ischemic burden, consider ASA monotherapy vs. clopidogrel without load
- **Associated vertebral ostial stenosis with basilar occlusion**
  - If possible, perform thrombectomy through contralateral (nondiseased) vertebral artery
  - If thrombectomy requires intervention through stenotic/occluded vertebral ostium
    - Angioplasty vertebral ostium without distal embolic protection
    - Use reperfusion catheter in basilar ± stent retriever
    - Stent vertebral ostium after basilar intervention complete
- **Extracranial carotid/vertebral dissection/stroke**
  - Similar approach to cervical carotid stenosis/occlusion
  - Distal embolic protection often not possible due to dissection extending to skull base
  - Cross dissection with microcatheter
  - Verify microcatheter placement in true lumen with DSA run
  - Over exchange wire, place self-expanding stent(s)
  - Stent often traps flap and thrombus restoring flow

Findings and Reporting

- Location/characteristics of lesion
- Devices/medications used intraprocedurally
- Procedure times
  - Door to groin time
  - Time of reperfusion
- TICI grade of perfusion after stroke intervention
  - Angiographic degree of reperfusion
    - 0: No perfusion beyond occlusion
    - 1: Penetration past occlusion but no perfusion
    - 2a: Partial perfusion; incomplete distal branch filling of < 50% of territory of occluded vessel
    - 2b: Partial perfusion; incomplete distal branch filling of ≥ 50% of territory of occluded vessel
    - 2c: Near-complete perfusion; no clearly visible thrombus but delayed contrast runoff
    - 3: Full perfusion; filling of all distal branches of expected territory in normal fashion
- Complications

Alternative Procedures/Therapies

- Radiologic
  - Direct carotid access if unable to select common carotid artery/ICA due to tortuosity
  - Intraarterial (IA) tPA
    - Once considered primary treatment, now only in rare select cases
  - Combined strategies: Intravenous followed by thrombectomy
- Surgical
  - Hemicraniectomy for large middle cerebral artery strokes to avoid herniation from edema

POST PROCEDURE

Things to Do

- Patient management after IA therapy
  - Admission to ICU
  - Neurologic exam/vital signs q 15 minutes 2 hours, q 30 minutes for 6 hours, q 1 hour for 24 hours
  - Maintain SBP 100-160 mm Hg

  - Head CT for any neurological status changes
- Postprocedure medications (procedure dependent)
  - If carotid stent required
    - ASA 325 mg, clopidogrel 150- to 300-mg loading dose (if ischemic burden low)
      - Maintain on daily clopidogrel 75 mg for 4-6 weeks, daily ASA 325 mg indefinitely
    - Atropine or glycopyrrolate for vagus nerve mediated bradycardia/hypotension; pressors if needed

OUTCOMES

Complications

- Brain hemorrhage
  - May categorize postthrombolysis hemorrhagic transformations (HT) by CT-based classification of European Cooperative Acute Stroke Study (ECASS)
    - No HT
    - Hemorrhagic infarct (HI) 1: Small petechiae
    - HI 2: Medium petechiae
    - Parenchymal hematoma type 1 (PH1): HI large (≤ 30% of infarcted area; mild mass effect)
    - PH2: Hematoma (≥ 30% of infarcted area; significant mass effect)
- Mechanical thrombectomy complications
  - Device-related complications
    - Vascular perforation
    - Arterial dissection
    - Embolization to previously uninvolved territory
- Worsening brain infarction
- Malignant brain edema of infarcted territory
- Bleeding/hematoma at arterial access site
- Angioplasty/stenting complications
  - Similar device-related complications
    - Vascular perforation
    - Arterial dissection
  - Vagus nerve mediated bradycardia/hypotension

Management of Complications

- Asymptomatic/small hemorrhage (< 30 mL)
  - Tight blood pressure control (SBP < 160 mm Hg)
  - Frequent neurological exams
  - Reverse anticoagulation
  - Consider giving clotting factors/platelets
- Symptomatic, significant hemorrhage (> 30 mL)
  - Reverse anticoagulation
  - Consider: Ventriculostomy (symptomatic hydrocephalus); craniotomy (clot evacuation)

Expected Outcomes

- Mechanical thrombectomy
  - Successful recanalization (72-93%)
  - Good clinical outcome; modified Rankin scale ≤ 2 at 90 days (51-60%)
  - Slight disability; able to look after own affairs without assistance, but unable to carry out all previous activities
  - Significant procedural complications (1-3%)
  - Symptomatic intracerebral hemorrhage (3.6%)
  - Mortality (10-12%)
  - Lower success rate and higher morbidity/mortality with basilar artery occlusions

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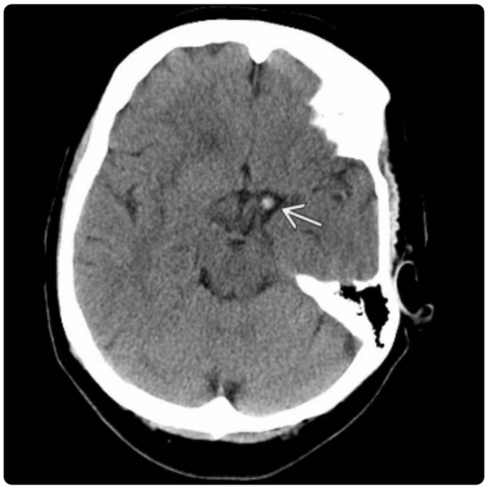
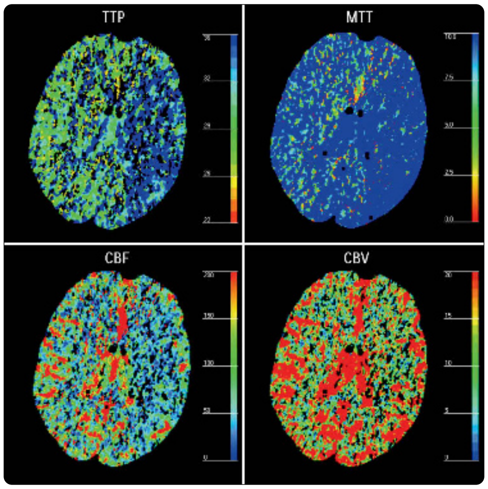
Left ICA Occlusion

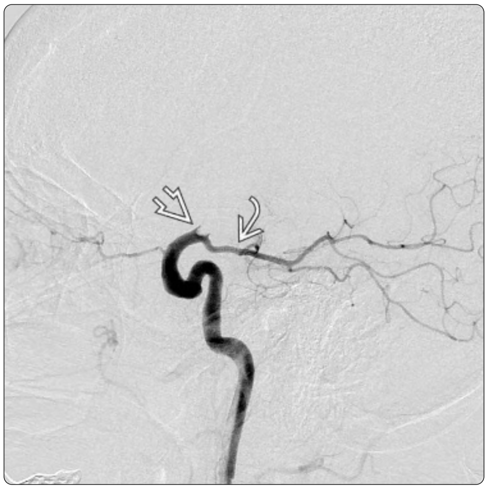


Left ICA Occlusion

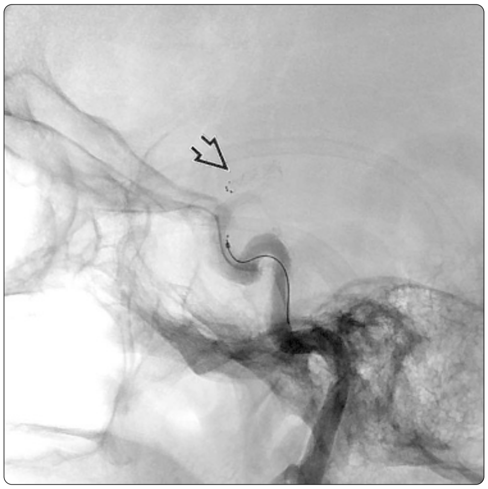


(Left) *NECT in a 52-year-old man presenting with acute-onset right hemiplegia, aphasia, and neglect demonstrates dense left ICA terminus* ➡. **(Right)** *CT perfusion of the same patient demonstrates a large ischemic penumbra in the left MCA and ACA territory secondary to the left ICA occlusion.*

Left ICA Terminus Occlusion

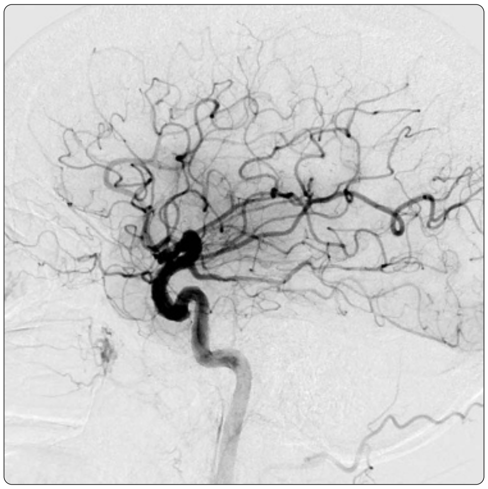


Left ICA Occlusion With Solitaire Deployed

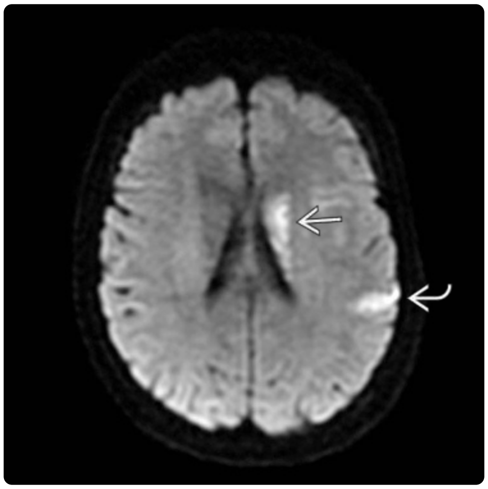


(Left) *Lateral digital subtraction angiogram demonstrates a filling defect within the distal left ICA* ⇨ *consistent with acute thromboembolus. There is no filling of the left ACA or MCA. The left posterior communicating artery* ↪ *is patent.* **(Right)** *Lateral unsubtracted angiogram shows the Solitaire device* ⇨ *deployed across the left ICA terminus occlusion.*

Postthrombectomy Angiogram



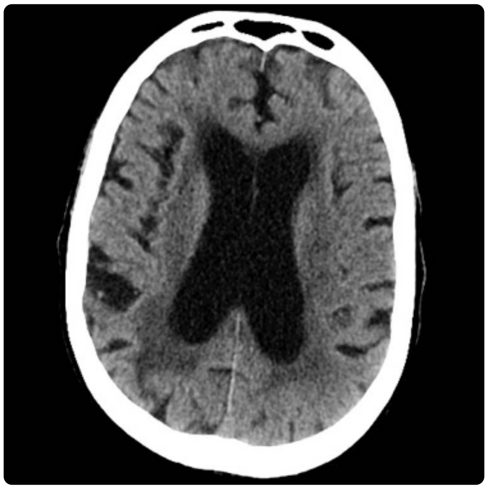
Left ICA Occlusion: Postthrombectomy MR



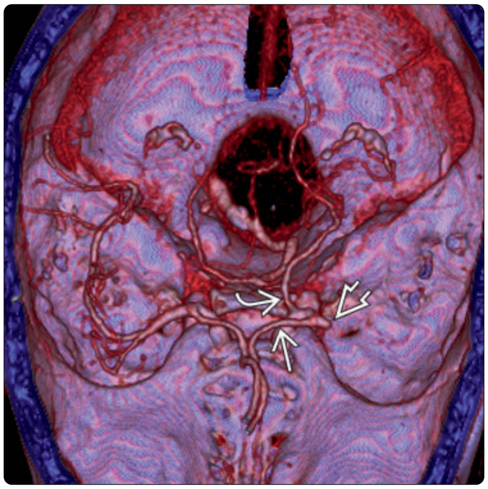
(Left) *Lateral digital subtraction angiogram from the left ICA demonstrates complete restoration of flow to the left ICA territory (TICI 3). This was obtained after 1 pass with the Solitaire 4 x 40-mm device.* **(Right)** *Axial DWI MR demonstrates small areas of acute infarction within the left caudate body* ➡ *and left parietal cortex* ↪. *These are significantly smaller than the ischemic penumbra on CT perfusion. There was no hemorrhage on GRE sequence (not pictured).*

(Left) *Sixty-five-year-old man presented with acute onset of right hemiplegia, facial droop, aphasia, and neglect 3.5 hours prior to arrival to ED. NIHSS was 21. NECT demonstrates no acute hemorrhage or gray-white loss. There is chronic small vessel ischemic disease.* **(Right)** *3D reformatted image from this patient's CT angiogram shows occlusion of the proximal left MCA, M1 segment ⇨. The left ACA → and fetal left PCA ↪ remain patent.*

Acute Left MCA M1 Stroke: Initial CT

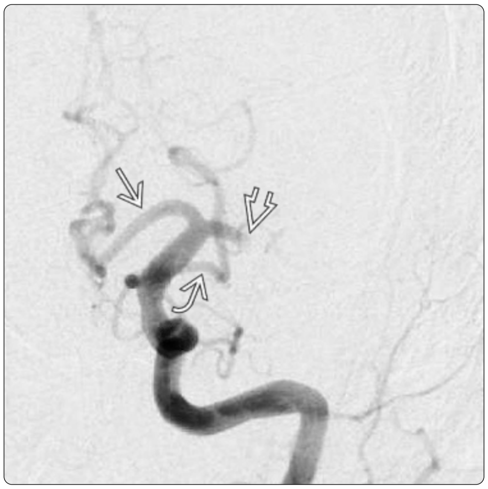


Acute Left MCA M1 Stroke: CT Angiogram

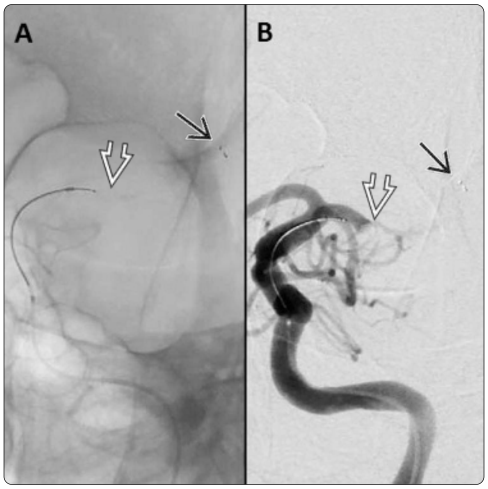


(Left) *DSA of the left ICA demonstrates abrupt occlusion of the left MCA, M1 segment ⇨. The left ACA → and fetal left PCA ↪ remain patent.* **(Right)** *Unsubtracted fluoroscopic image (A) and digital subtraction angiogram (B) show deployment of the stent retriever device across the left MCA, M1 segment thrombus ⇨. Note only the distal markers of the Solitaire device ➔ are radiopaque.*

Acute Left MCA M1 Stroke: Initial Angiogram

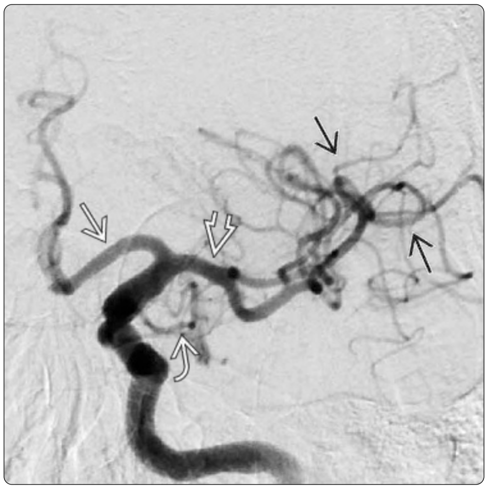


Acute Left MCA M1 Stroke: Solitaire Device

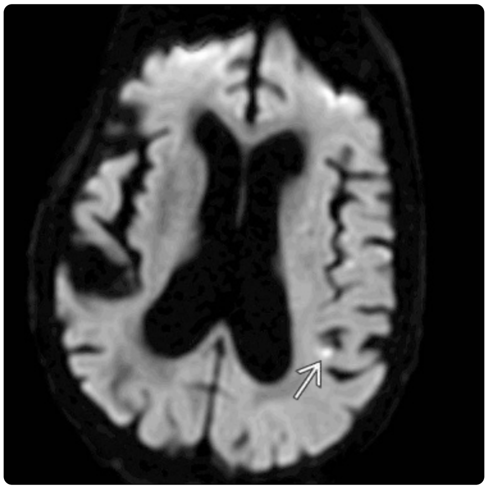


(Left) *DSA following mechanical thrombectomy shows restoration of flow to the left MCA ⇨ with TICI 3 flow in the distal branches ➔. Two passes with the Solitaire device were required in this patient. The left ACA → and fetal left PCA ↪ remain patent.* **(Right)** *Axial DWI MR demonstrates only a punctate area of acute infarction in the left MCA territory →. There was no hemorrhage on gradient echo sequence (not pictured).*

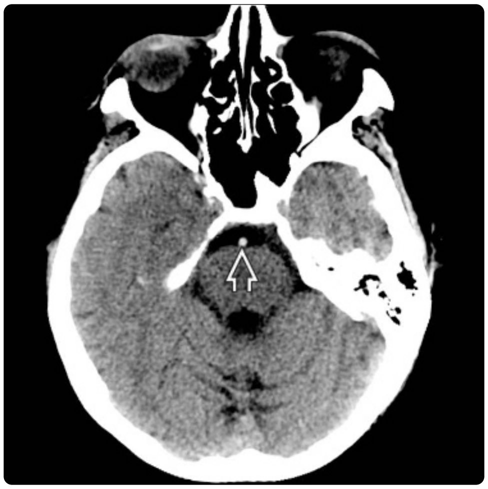
Acute Left MCA M1 Stroke: Post Thrombectomy



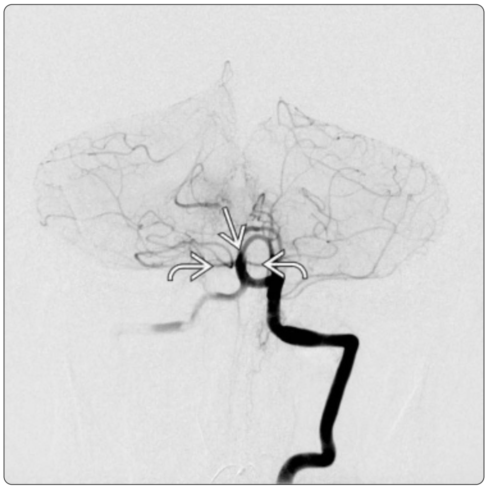
Acute Left MCA M1 Stroke: DWI MR



Basilar Stroke Intervention: Initial NECT Imaging

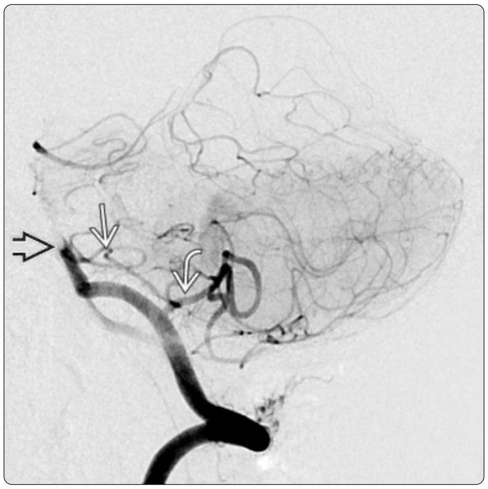


Basilar Stroke Intervention: AP Basilar Arteriogram

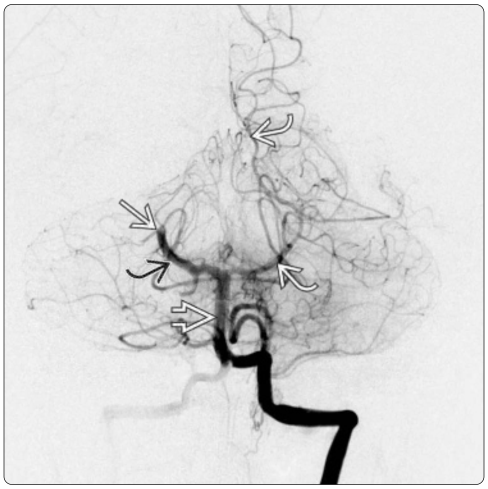


(Left) *Axial NECT of a patient with an acute stroke shows a hyperdense basilar artery ⇨ believed to represent intraluminal clot. NECT is initially obtained in acute stroke to exclude intracranial hemorrhage, which is a thrombolysis contraindication.* **(Right)** *Selective AP left vertebral DSA obtained in preparation for transcatheter treatment of acute thrombotic occlusion of the basilar artery shows the level of occlusion → is just distal to the anterior inferior cerebellar arteries (AICAs) ↪.*

Basilar Stroke Intervention: Lateral Basilar Arteriogram

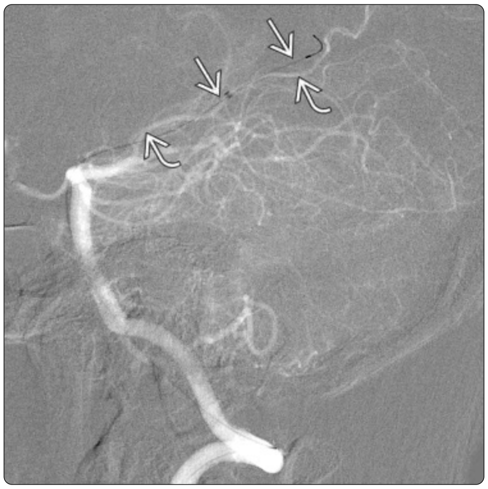


Basilar Stroke Intervention: DSA After Thrombectomy

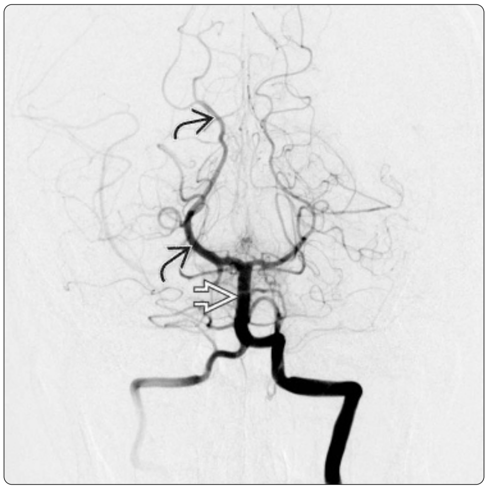


(Left) *The basilar artery occlusion is better demonstrated on the lateral DSA arteriogram, with a meniscus ⇨ seen at the inferior margin of the occluding thrombus in the basilar artery. In addition to the AICAs →, the left posterior inferior cerebellar artery (PICA) ↪ remains patent.* **(Right)** *DSA following thrombectomy shows improved basilar artery patency ⇨ and flow in the left posterior cerebral artery (PCA) ↪. There is perfusion of the proximal right PCA ↪, which terminates abruptly →.*

Basilar Stroke Intervention: Penumbra System Thromboaspiration



Basilar Stroke Intervention: Completion Basilar Arteriogram



(Left) *Lateral road map fluoroscopy shows that a reperfusion catheter → has been advanced distally in the right PCA in an attempt to restore perfusion using thromboaspiration. The patent contralateral left PCA ↪ can be seen for comparison.* **(Right)** *Final DSA after aspiration use shows that the right PCA ↪ is perfused throughout the entire length. The basilar artery ⇨ has a normal appearance, as do all branch vessels. This is an example of TICI grade 3 reperfusion.*

Carotid or Vertebral Angioplasty/Stenting

KEY FACTS

TERMINOLOGY

- Severe carotid artery stenosis: ≥ 70% diameter stenosis
- Preocclusive carotid stenosis: ≥ 90% diameter stenosis
- Embolic protection device (EPD): Intravascular device designed to prevent dislodged plaque/debris/embolic material from occluding distal vasculature

PREPROCEDURE

- Indications for carotid/vertebral artery stenting (CAS/VAS)
  - Patient high risk for carotid endarterectomy (CEA) due to comorbidities or anatomic challenges
  - Symptomatic
    - > 50% carotid stenosis by DSA (> 70% by US)
  - Asymptomatic
    - > 60% carotid stenosis by DSA (> 70% by US)
  - Vertebrobasilar insufficiency symptoms
- Preprocedure imaging
  - Carotid duplex US/CTA/MRA/DSA

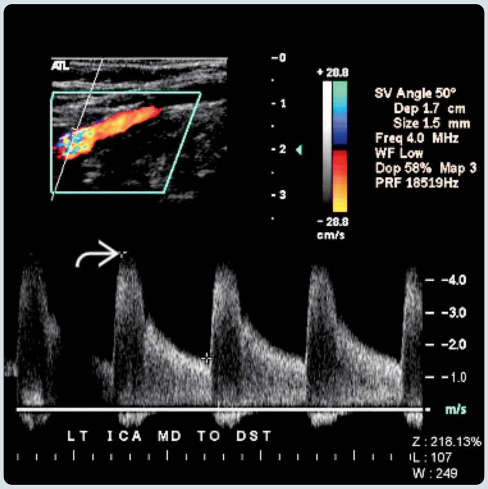
PROCEDURE

- Heparinize patient intraprocedurally
- Perform selective carotid/vertebral DSA
- Cross stenosis with microwire
- Deploy EPD prior to angioplasty/stenting
- Angioplasty lesion if high-grade stenosis
- Place/deploy stent across stenosis
  - Carotid: Extend between normal common/internal carotid artery (CCA/ICA) segments
  - Vertebral: Extend distal to lesion; 1-2 mm into subclavian artery
- Postdilate stent with PTA if needed
- Obtain completion DSA images
- Remove EPD: Repeat DSA including intracranial; document results and cerebral perfusion

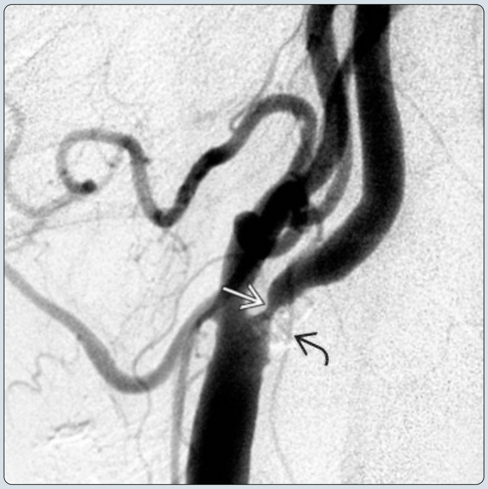
OUTCOMES

- Goal: Resolution of stenosis without adverse event
  - Reported 4-6% 30-day risk of stroke and death

Complication of Carotid Stenting (Initial Color Doppler US)

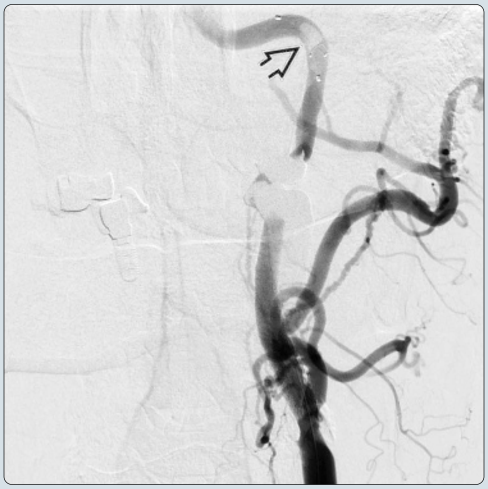


Carotid Angiogram

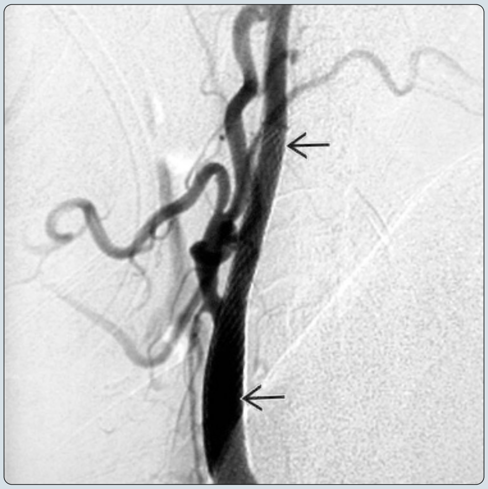


(Left) *Color Doppler US obtained in a patient with symptoms suggesting a left carotid stenosis shows marked elevation (> 4.0 m/s) of the peak systolic velocity* ↪ *in the mid to distal left internal carotid artery (ICA). This is consistent with severe ICA stenosis.* **(Right)** *DSA of carotid artery bifurcation shows an 80% stenosis of the proximal ICA* ➡ *caused by eccentric calcified atheromatous plaque* ↪ *in a symptomatic clinical trial patient.*

Embolic Protection Device



Carotid Angiogram Post Stent



(Left) *Oblique DSA in a different patient shows thrombus (filling defect) within the distal embolic protection device (EPD)* ⇨*. The device was only slightly recaptured prior to removal to prevent dislodging this thrombus. There was a large visible thrombus within the device upon retrieval.* **(Right)** *Common carotid artery (CCA) DSA after angioplasty and carotid artery stenting shows a normal vessel diameter along the stented segment* ⇨*. The tapered carotid stent extends from the CCA into the ICA.*

TERMINOLOGY

Definitions

- **North American Symptomatic Carotid Endarterectomy Trial (NASCET)**: Randomized study; defined carotid revascularization indications
    - Severe carotid artery stenosis: ≥ 70% diameter stenosis
    - Preocclusive carotid stenosis: ≥ 90% diameter stenosis
- **Embolic protection device (EPD)**: Intravascular device designed to prevent dislodged plaque/debris/embolic material from occluding distal vasculature

PREPROCEDURE

Indications

- **Carotid stent for atherosclerotic stenotic disease**
    - Acute ischemia with concurrent intracranial occlusion requiring emergent mechanical thrombectomy
    - Patients at high risk for carotid endarterectomy (CEA) due to anatomy/comorbidities
        - Recurrent carotid stenosis after CEA
        - Contralateral carotid artery occlusion
        - Prior neck radiation treatment or surgery
        - Severe cardiac or pulmonary disease
        - Surgically inaccessible high cervical segment lesions
    - FDA-approved carotid artery stenting (CAS) with embolic protection device with these criteria
        - Symptomatic
            - > 50% CCA/ICA stenosis by DSA (> 70% by US)
        - Asymptomatic
            - > 60% CCA/ICA stenosis by DSA (> 70% by US)
        - Reference vessel diameter within 4-9 mm range at target lesion
    - Must use EPD for reimbursement
- **Vertebral artery stenting** (VAS)
    - Recurrent vertebrobasilar insufficiency, refractory to medical therapy
    - CT/MR evidence of posterior circulation ischemia
    - ≥ 50% vertebral artery stenosis (CTA/DSA)
    - Contralateral vertebral artery hypoplasia/stenosis
- **Carotid stent for dissection/pseudoaneurysm**
    - Hemodynamically significant carotid artery dissection/pseudoaneurysm; symptomatic despite antiplatelet/anticoagulant therapy
- **Common carotid artery origin stent**
    - Symptomatic stenosis > 50% by CTA/DSA/MRA
    - Significant CCA origin stenosis in tandem with distal CCA/ICA lesion for which CAS planned

Contraindications

- **Absolute contraindications**
    - High risk of crossing stenosis with guidewire/stent
        - Extreme tortuosity, unstable plaque
- **Relative contraindications**
    - Symptomatic stenosis associated with
        - Intracranial vascular malformation
        - Large subacute cerebral infarction
        - Contrast allergy, renal dysfunction
    - Bleeding diathesis/anticoagulation contraindication
    - Contraindication to dual antiplatelet therapy
    - Hypercoagulability

Preprocedure Imaging

- Imaging: Carotid duplex US/CTA/MRA/DSA

Getting Started

- Things to check
    - Clinical history and physical examination
        - Detailed neurological examination
        - Medications (anticoagulant, antiplatelet agents)
        - Any history of cardiovascular disease
    - Allergies
    - Laboratory parameters
        - Electrolytes, glomerular filtration rate (eGFR)
            - Prefer normal Cr; eGFR > 60
        - Complete blood count (CBC)
            - Platelet count > 50,000/μL
        - Coagulation profile
            - International normalized ratio (INR) ≤ 1.5
- Medications
    - Stop oral anticoagulants 5 days before procedure, bridge with low molecular heparin if necessary
    - Give antiplatelet agents (clopidogrel 75 mg/aspirin 325 mg daily) 3-5 days before procedure
        - Or loading dose of aspirin 325 mg/clopidogrel 300-600 mg at least 5 hours before procedure
        - In emergency, give IV heparin or GP IIb/IIIa inhibitor as "bridge to therapy" until ASA/clopidogrel loading dose given and allowed time to take effect (2-5 hours)
    - Heparin (bolus 70 U/kg)
    - Glycopyrrolate (0.2-0.6 mg) or atropine (0.5-1.0 mg) before carotid stenosis PTA
    - Nitroglycerin (100 μg bolus) or nitropaste for vasospasm
    - No antihypertensive medications on procedure day
- Equipment list
    - Sheaths/catheters
        - Arterial access sheath (5-8 Fr)
        - Long arterial guiding sheath (6 Fr)
        - Selective diagnostic catheter
    - Guidewires
        - J-tip or floppy tip 0.035" guidewire (initial access)
        - Hydrophilic 0.035" guidewire (selective carotid/vertebral catheterization)
        - Stiff guidewire (guiding sheath introduction)
    - Embolic protection device
        - Various types available with differing mechanisms of action
    - Angioplasty balloon catheters
        - Various proprietary designs available
        - Typically use rapid exchange design
    - Stents
        - Various configurations & proprietary designs available
            - Tapered vs. nontapered configuration
            - Open-cell vs. closed-cell design

PROCEDURE

Procedure Steps

- **General**
    - Sterilely prepare and drape groin
    - Obtain transfemoral arterial access
    - Administer heparin bolus (loading dose 70 U/kg)

    - Maintain activated clotting time of 250-300 s
  - Introduce diagnostic catheter
  - Selectively catheterize target artery
    - Obtain DSA images of target artery
    - Obtain DSA cerebral angiographic images
      - Prestent assessment of intracranial circulation
  - Advance guiding sheath over diagnostic catheter; position proximal to stenosis
  - Base EPD size on arterial diameter where deployed
  - Deploy EPD
    - Filter & balloon occlusion EPDs require initially crossing stenosis before deployment
    - Minimize vasospasm with correct size EPD and limited movement after deployment
  - Predilate lesion with angioplasty if tight stenosis
    - Use small-diameter balloon (e.g., 3-4 mm)
    - Nitroglycerin or nitropaste for vasospasm
    - Glycopyrrolate or atropine for bradycardia
  - Position stent across stenosis
    - Stent should extend across entire lesion; bridge between healthy vascular segments
  - Deploy stent
    - Obtain postdeployment DSA images
      - Confirm stent position & expansion
      - Maintain guidewire access & EPD position
  - Postdilate stent, if indicated on DSA images
    - Balloon size based upon healthy target vessel diameter
  - Repeat DSA images of target area after postdilation
    - Include EPD; assess visible embolic burden and vasospasm
  - Remove EPD
    - If visible thrombus within EPD, then do not fully recapture filter basket
  - Obtain final DSA of target/cerebral vasculature
    - Document final appearance of stented segment
    - Assess poststent intracranial circulation integrity
  - Remove catheter/sheaths
  - Obtain hemostasis at access site
- **Carotid artery stent**
  - Filter/balloon occlusion type EPD should be deployed in distal cervical/petrous ICA segment
  - For carotid bifurcation disease
    - Stent should span disease-free CCA & ICA segments
  - Possible bradycardia/asystole during PTA
    - Stimulation of carotid body baroreceptor
    - Glycopyrrolate 0.2-0.6 mg or atropine 0.5-1.0 mg IV for bradycardia
    - Hypotension may require dopamine (or other vasopressor) infusion
  - Marked intraprocedural ICA vasospasm may occur
    - Often related to EPD or guidewire manipulation
    - Nitroglycerin (100 μg bolus) or nitropaste for vasospasm
- **Vertebral artery stent**
  - Position guiding sheath/catheter in subclavian artery adjacent to vertebral artery
  - Deploy EPD for vertebral artery > 3.5 mm
  - Match stent to arterial diameter distal to lesion
    - Stent should extend 1-2 mm into subclavian artery and 3-5 mm distal to lesion

Alternative Procedures/Therapies

- Radiologic
  - Balloon angioplasty
- Surgical
  - Carotid endarterectomy

POST PROCEDURE

Things to Do

- Continue daily dual antiplatelet therapy with clopidogrel 75 mg and aspirin 81 mg for 6 weeks to 3 months
- Continue daily aspirin 81-325 mg for life
- Surveillance carotid US at 6 weeks and 12 months

Things to Avoid

- Poor blood pressure control after procedure

OUTCOMES

Problems

- Postprocedure hypotension and bradycardia
  - Treat with pressors
  - Usually self-limited; resolves within 1-2 days
  - Do cardiac work-up to exclude myocardial infarction

Complications

- Most feared complication(s)
  - Adverse neurologic event (TIA/stroke)
  - Hyperperfusion syndrome: Failure of autoregulation of cerebral perfusion after CAS (1.45% incidence)
    - Headache, seizure, intracranial hemorrhage, altered mental status, focal neurological changes
    - Maintain SBP < 100-140
  - Persistent bradycardia/hypotension
- Delayed complication(s)
  - In-stent restenosis
    - 3-11% reported > 50% incidence of restenosis
      - Treat with angioplasty/repeat stenting
    - Comparable to 10% incidence reported for CEA

Expected Outcomes

- Resolution of stenosis without adverse event
  - Reported 4-6% 30-day risk of stroke and death

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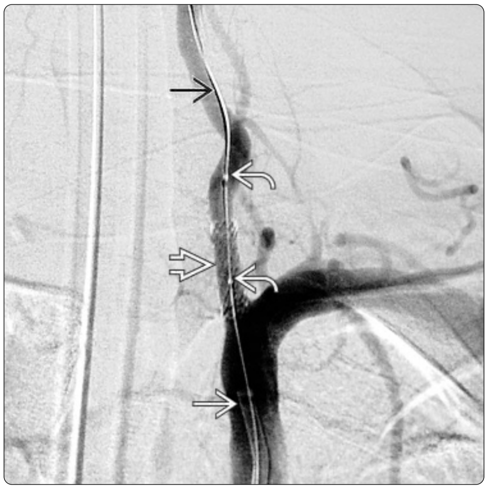
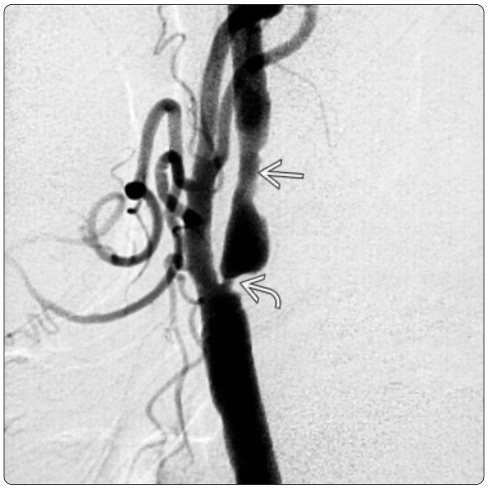
3. Brott TG et al: Stenting versus endarterectomy for treatment of carotid-artery stenosis. N Engl J Med. 363(1):11-23, 2010
4. Chaer RA et al: Cerebral reserve is decreased in elderly patients with carotid stenosis. J Vasc Surg. 52(3):569-74; discussion 574-5, 2010
5. Davis SM et al: Carotid-artery stenting in stroke prevention. N Engl J Med. 363(1):80-2, 2010
6. Paraskevas KI: Carotid artery stenting vs endarterectomy for carotid stenosis. Lancet. 376(9738):327, 2010
7. Gurm HS et al: Long-term results of carotid stenting versus endarterectomy in high-risk patients. N Engl J Med. 358(15):1572-9, 2008

Vertebral Artery Stent (DSA After Stenting)

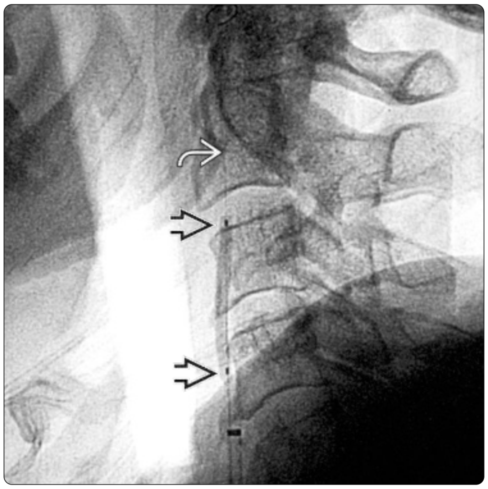


Carotid Artery Stent Procedure (Common Carotid Artery DSA)

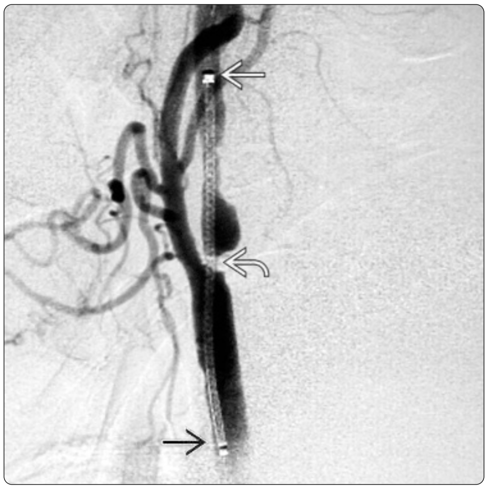


(Left) *Left subclavian DSA obtained after placement of a balloon expandable stent ⇨ for a left vertebral artery origin stenosis shows the guidecatheter ➡, the 0.014" guidewire →, and the radiopaque markers ↪ of the deflated angioplasty balloon.* **(Right)** *Lateral DSA from a selective CCA injection shows a severe 80% stenosis ↪ at the origin of the ICA. There is a 2nd, less severe area of stenosis ➡ more distally.*

Carotid Artery Stent Procedure (Angioplasty Prior to Stenting)

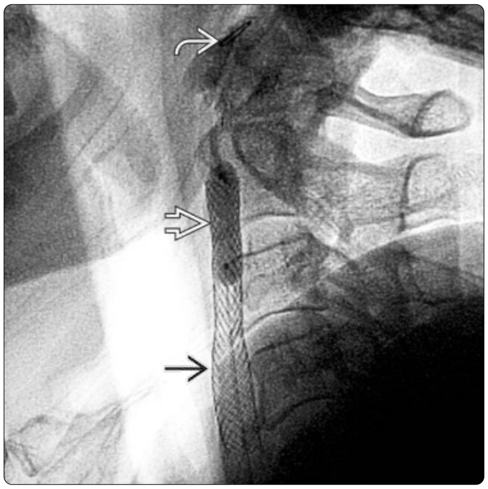


Carotid Artery Stent Procedure (Stent Position Before Deployment)

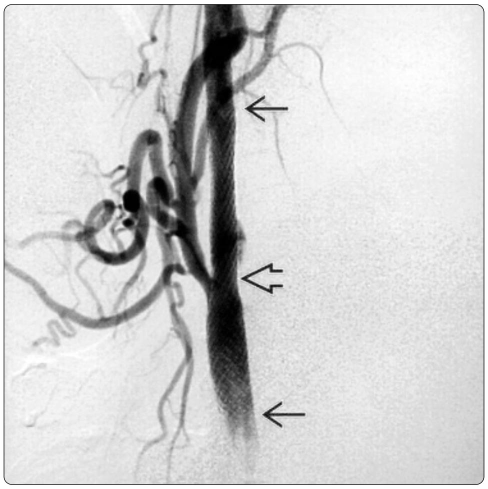


(Left) *Lateral intraoperative fluoroscopic spot image shows a 2.5 x 30 mm balloon ⇨ advanced over a microwire ↪, predilating severe internal carotid stenosis.* **(Right)** *DSA during positioning of the stent across the stenosis ↪ shows that the distal end of the stent ➡ is positioned in the ICA and that the proximal end → extends into the CCA. It is important that the stent extends to healthy vascular tissue on either end.*

Carotid Artery Stent Procedure (Angioplasty After Stenting)



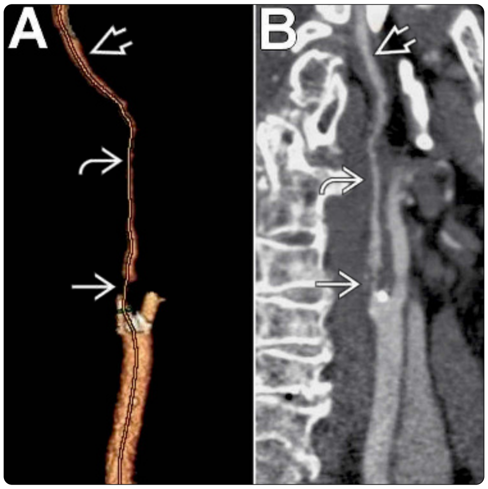
Carotid Artery Stent Procedure (Final Common Carotid Artery DSA)



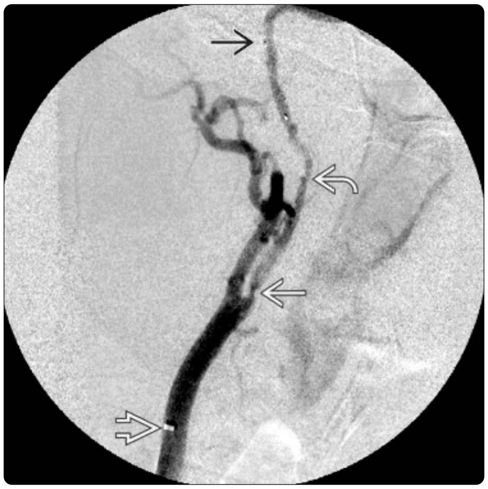
(Left) *After deployment of the self-expanding stent →, it was necessary to postdilate the stent using a 6 x 20 mm balloon ⇨. Note the embolic protection device ↪ remains in position in the distal ICA. The embolic protection device removal should be the final step in the procedure.* **(Right)** *CCA DSA after carotid stenting and angioplasty shows satisfactory positioning of the stent → and restoration of a normal arterial diameter ⇨, where there was previously a severe stenosis. The EPD has been recaptured and removed.*

(Left) *CTA images obtained in a patient with a symptomatic ICA stenosis were reformatted as (A) 3D and (B) sagittal reconstructions. Both confirm a severe proximal ICA stenosis → with a diminutive ICA ↪ distal to the stenosis. Near the petrous portion of the artery, the caliber increases ⇨. High-quality preprocedural imaging is critical to achieving good CAS outcomes.* **(Right)** *DSA shows the ICA stenosis → and diminutive distal ICA ↪. A guiding sheath ⇨ is in the CCA, and an EPD ⇒ has been deployed in the distal ICA prior to angioplasty and CAS.*

Carotid Artery Stent Procedure (Preprocedure CTA Imaging)

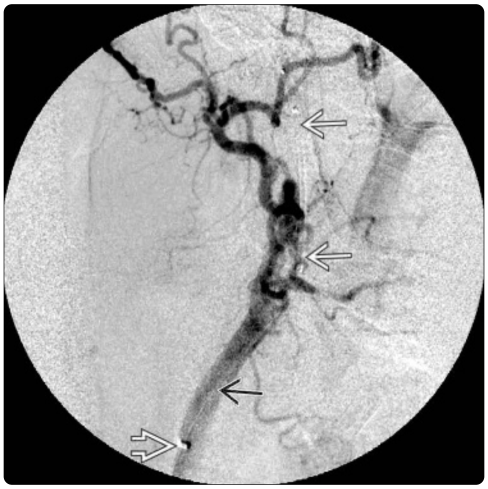


Carotid Artery Stent Procedure (DSA After Placement of EPD)

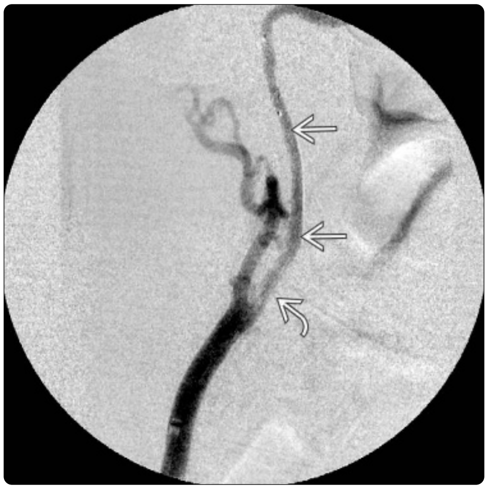


(Left) *The severe proximal ICA stenosis was predilated with a 3-mm PTA balloon. A self-expanding stent → was then introduced over the guidewire ⇒ through the guiding sheath ⇨ and was advanced into the distal ICA segment.* **(Right)** *DSA obtained after deployment of the stent → in the distal ICA shows marked improvement to the luminal caliber. There is an irregular appearance to the proximal ICA ↪, where the severe stenosis was predilated prior to stenting. A 2nd stent is required for complete treatment of the diseased ICA.*

Carotid Artery Stent Procedure (Stent Position Before Deployment)

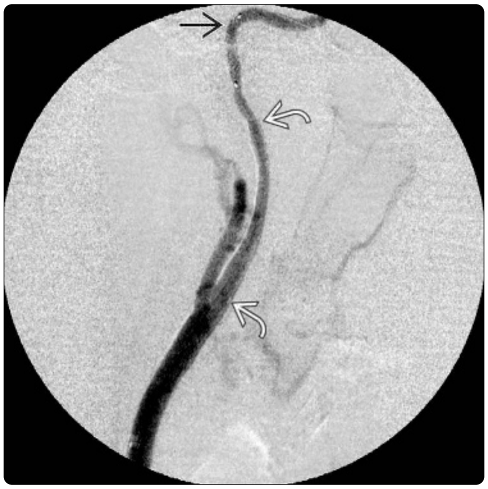


Carotid Artery Stent Procedure (Stent Position After Deployment)

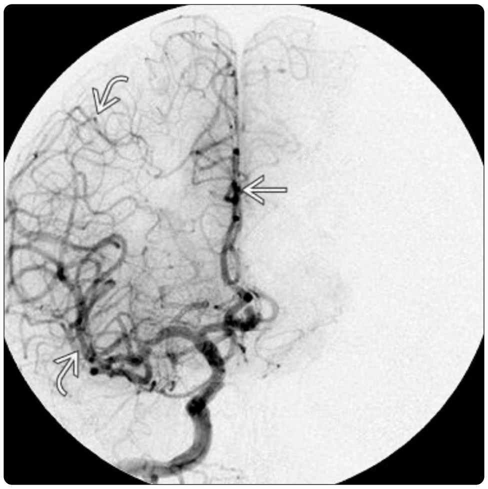


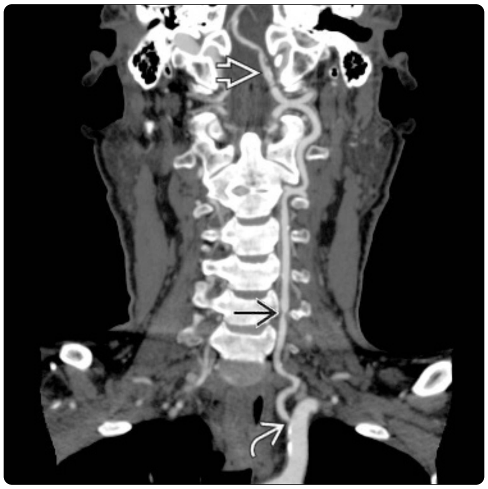
(Left) *Lateral DSA obtained after placement of the tandem 2nd stent shows restoration of a normal luminal caliber along the stented segment ↪ of the ICA. The filter-type EPD ⇒ remains in place. This will be recaptured and removed with a retrieval catheter. EPD use is FDA mandated and has decreased CAS complications.* **(Right)** *DSA of the intracranial circulation after EPD removal shows satisfactory perfusion of the anterior → and middle cerebral ↪ arterial territories. It is important to document the status of the intracranial circulation after CAS.*

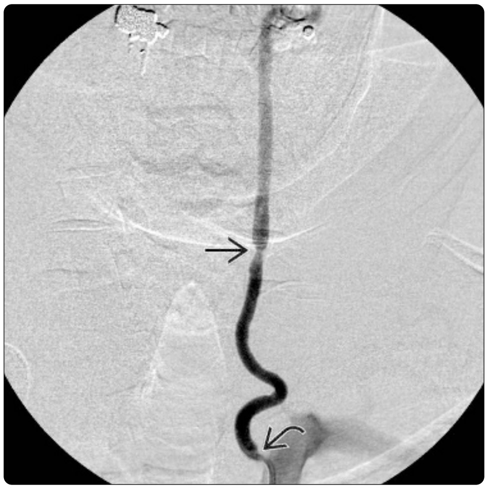
Carotid Artery Stent Procedure (DSA After Placement of 2nd Stent)



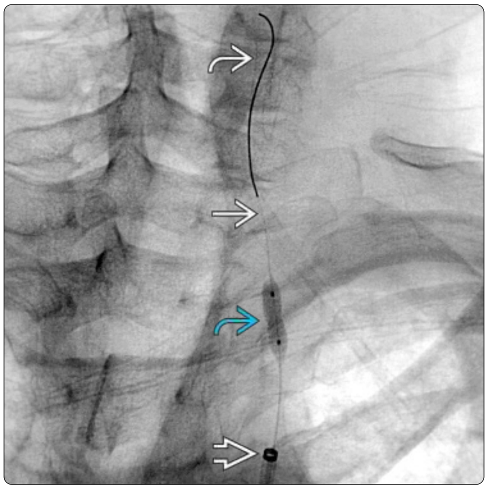
Carotid Artery Stent Procedure (DSA of Intracranial Vasculature)

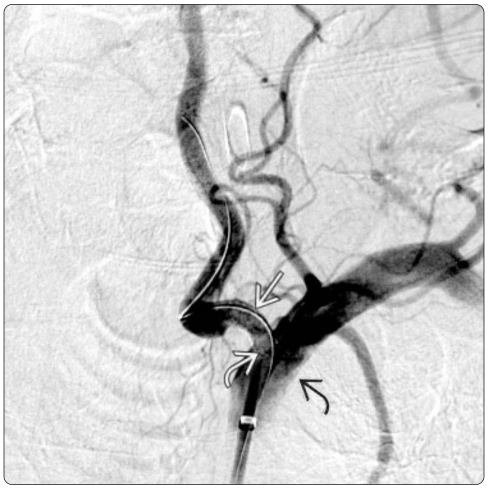



Vertebral Artery Stent Procedure (Initial CECT Evaluation)

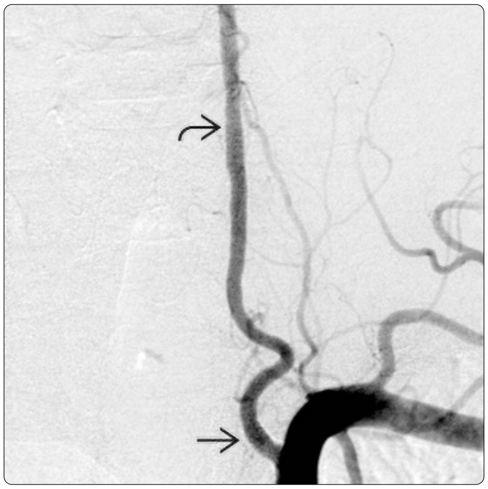

Vertebral Artery Stent Procedure (Selective Vertebral Artery DSA)

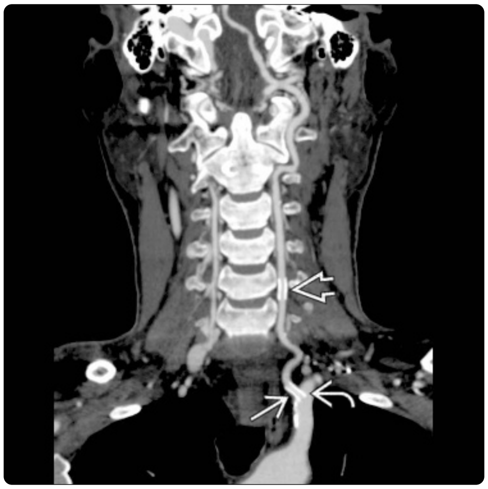
(Left) *Coronal CTA in a patient with symptoms of vertebrobasilar insufficiency shows a high-grade left vertebral origin stenosis* ↪*, as well as an additional stenosis* → *in the proximal 1/3 of the vertebral artery. Intracranial atherosclerotic disease* ⇨ *is also evident.* **(Right)** *Selective DSA of the left vertebral artery confirms both the original stenosis* ↪ *and the 2nd stenosis* → *in the proximal 1/3 of the artery. Based upon the symptoms and imaging findings, vertebral artery stenting was felt to be an appropriate treatment.*


Vertebral Artery Stent Procedure (Balloon-Mounted Stent Placement)


Vertebral Artery Stent Procedure (DSA Prior to Guidewire Removal)

(Left) *Fluoroscopic spot radiography shows a guiding sheath* ⇨ *positioned in the left subclavian artery, through which a guidewire* ➡ *has been advanced across both stenoses. The more cephalad lesion has already been stented* ↪*, and a balloon-mounted stent* ↪ *is positioned at the proximal stenosis.* **(Right)** *DSA from injection of the sheath shows the proximal stent* ➡ *in satisfactory position without residual stenosis. The proximal stent* ↪ *extends slightly into the subclavian artery* ↪ *to prevent restenosis.*

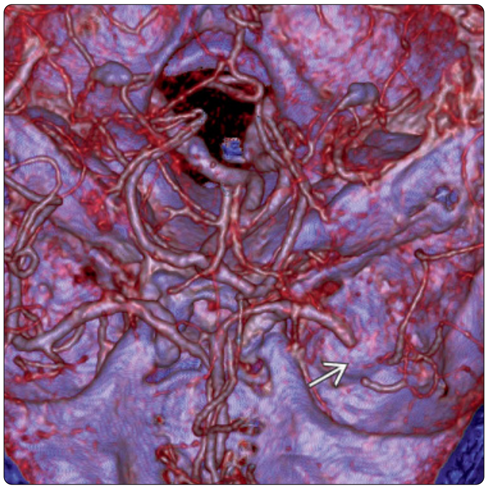

Vertebral Artery Stent Procedure (Post Stenting Completion DSA)


Vertebral Artery Stent Procedure (Follow-up Surveillance CTA)

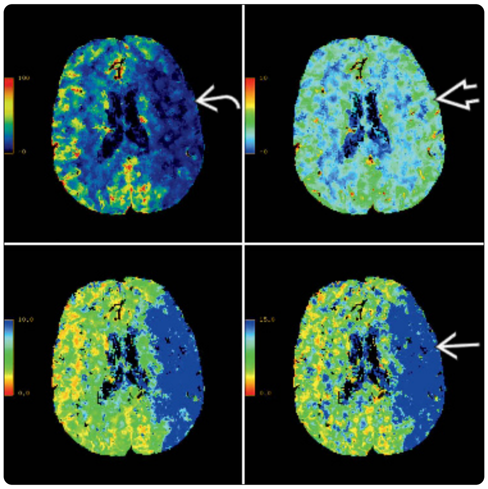
(Left) *DSA following stenting of the tandem stenoses and guidewire removal shows a normal caliber throughout the left vertebral artery. The stents in the cephalad* ↪ *and origin* → *portions of the left vertebral artery are faintly visible.* **(Right)** *Coronal CTA following stenting clearly shows the positions of the distal* ⇨ *and proximal* ➡ *stents. Again note the slight protrusion* ↪ *of the proximal stent into the left subclavian artery. This stent position is necessary in order to ensure complete coverage of the lesion.*

(Left) *3D CTA in a 62-year-old patient who presented acutely with right hemiplegia and aphasia shows occlusion of the left MCA, distal M1 segment* ➡*. Intracranial occlusion requiring mechanical thrombectomy is an indication for emergent carotid stenting if there is an ipsilateral, high-grade carotid stenosis.* **(Right)** *CT perfusion in the same patient shows increased mean transit time (MTT) in left MCA territory* ➡ *with decreased cerebral blood flow (CBF)* ➡ *and preserved cerebral blood volume (CBV)* ➡ *consistent with large ischemic penumbra.*

Left ICA and MCA Occlusions (3D CTA)

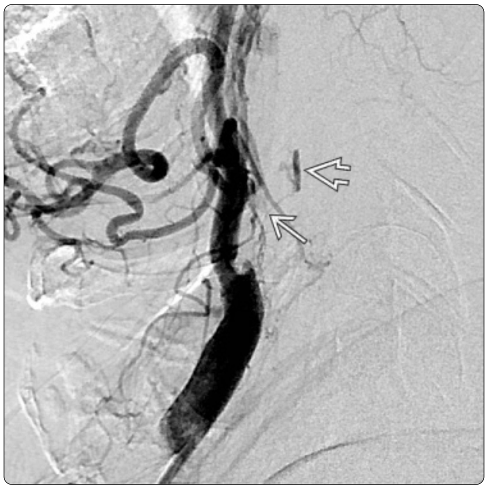


Left ICA and MCA Occlusions (CT Perfusion)

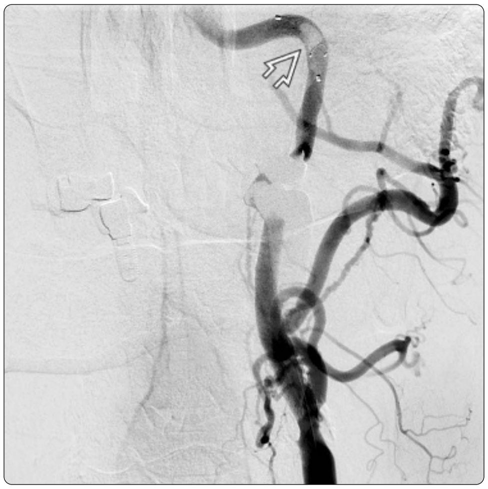


(Left) *Lateral DSA of the same patient shows occlusion of the left internal carotid artery. There is a string of contrast* ➡*, which opacifies the lumen of the ICA* ➡ *above the severe stenosis.* **(Right)** *Oblique DSA shows embolic plaque (filling defect)* ➡ *within the EPD seen following initial angioplasty. The patient was successfully stented. The EPD was only partially recaptured to prevent dislodging the plaque from the filter device. There was visible plaque in the device upon retrieval.*

Left ICA and MCA Occlusions (Diagnostic Arteriogram)

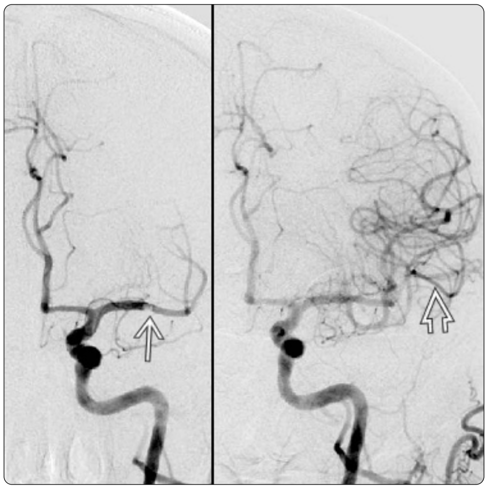


Left ICA and MCA Occlusions (Post Angioplasty & Stenting)

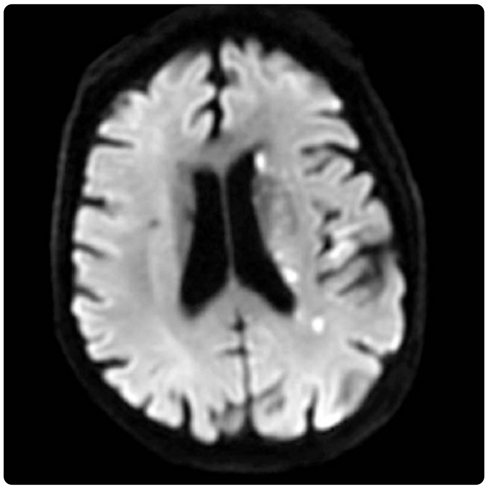


(Left) *Left MCA thrombectomy was then performed on the preexisting MCA occlusion* ➡*. The balloon guidecatheter was positioned above the carotid stent to prevent the stent retriever from crossing the stent. Thrombus was retrieved, and MCA flow was restored* ➡ *following thrombectomy.* **(Right)** *Axial DWI MR performed the next day demonstrates minimal ischemic burden compared to the initial ischemic penumbra. The patient made a significant improvement after stenting and thrombectomy.*

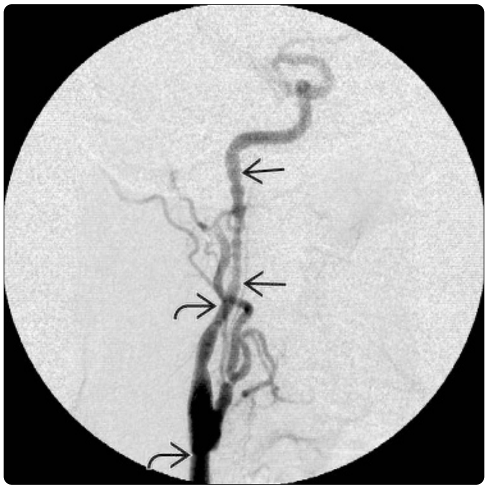
Left ICA and MCA Occlusions



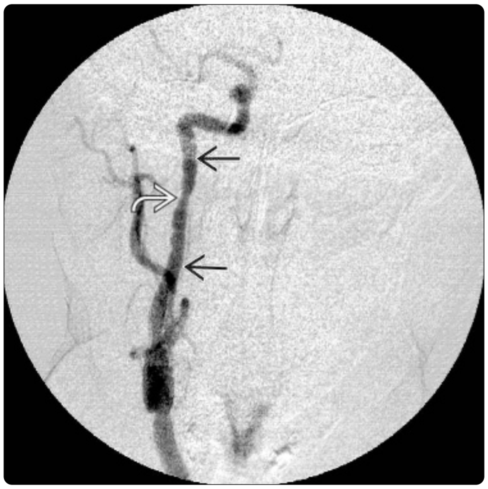
Left ICA and MCA Occlusions (Posttreatment MR)



Intraprocedural Vasospasm (Severe Vasospasm of ICA)

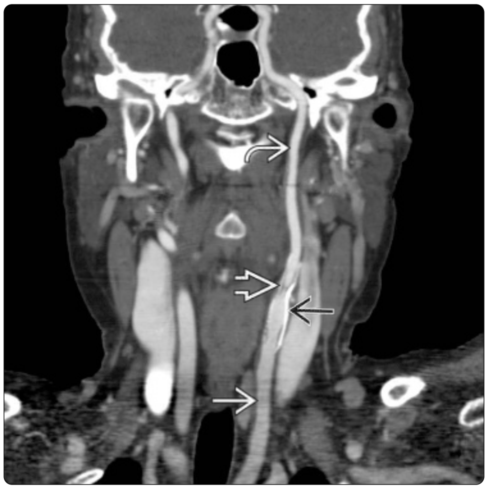


Intraprocedural Vasospasm (Improvement After Nitroglycerin)

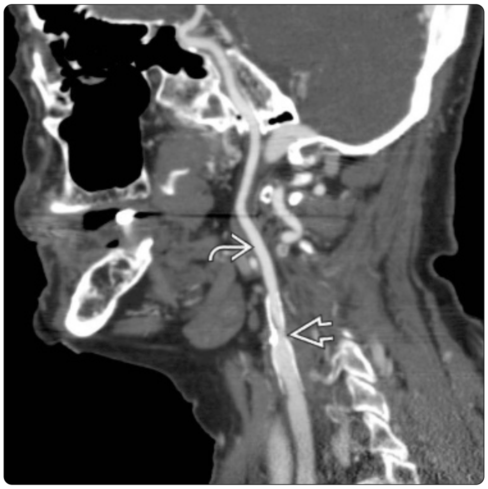


(Left) *Carotid DSA after stenting and retrieval of the EPD shows vasospasm → along a lengthy segment of the ICA distal to the stent ↪. Untreated severe vasospasm can cause intra- or periprocedural stroke.* **(Right)** *Repeat DSA after administration of 100 µg of intraarterial nitroglycerin via a sheath in the proximal CCA shows improvement in the vasospasm →. Some degree of persistent vasospasm ↪ is still evident.*

In-Stent Stenosis Complication (Initial CTA Evaluation)

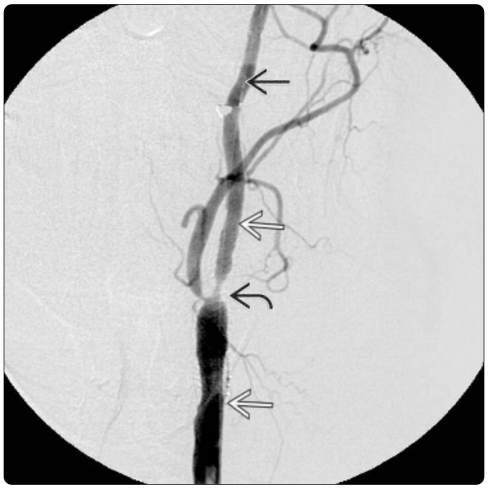


In-Stent Stenosis Complication (Initial CTA Evaluation)

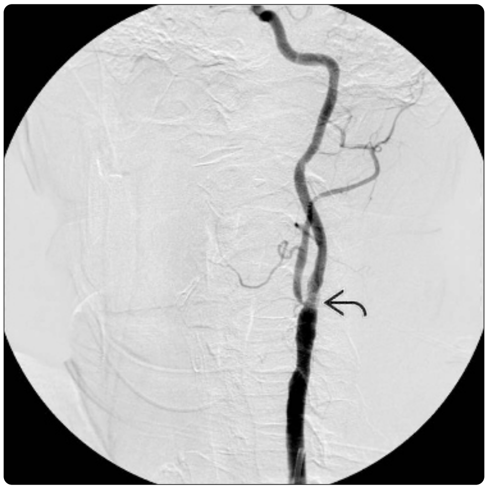


(Left) *Curved reformatted coronal CTA of the left common → and internal carotid ↪ arteries shows a severe stenosis ⇨ within a previously placed left carotid stent →. In-stent restenosis results from neointimal hyperplasia. The reported incidence varies from 3% up to 11.5% for stenoses > 50%.* **(Right)** *Curved reformatted sagittal CTA confirms the stenosis ⇨, with a normal internal carotid artery ↪ distally. In-stent stenoses can be treated with angioplasty, with re-stenting reserved for PTA failures.*

In-Stent Stenosis Complication (Common Carotid Artery DSA)



In-Stent Stenosis Complication (DSA Following Angioplasty)



(Left) *DSA shows the previously placed stent → extending from the distal CCA to the proximal ICA. The severe in-stent stenosis ↪ localizes to the level of the ICA origin. A guidewire → is in place, and an EPD was deployed in the distal ICA.* **(Right)** *DSA following angioplasty shows improved stenosis, with some minimal residual irregularity ↪ at the treatment area. Patients should be followed with surveillance US after initial stenting as well as after reintervention.*

KEY FACTS

TERMINOLOGY

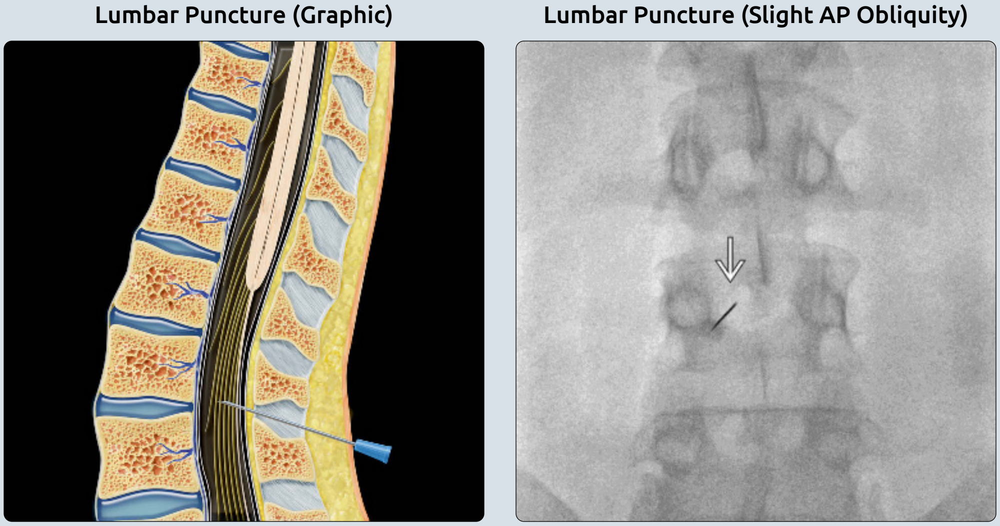
- Lumbar puncture: Insertion of spinal needle into thecal sac for diagnostic retrieval of CSF &/or injection of therapeutic or other diagnostic material
- Myelogram: Lumbar puncture with injection of myelography-safe iodinated contrast into thecal sac to visualize spinal canal, spinal cord and nerve roots
- Epidural blood patch: Injection of autologous blood into epidural space to treat spinal leak from prior dural puncture

PREPROCEDURE

- Indications include evaluation for CNS infection/inflammation, occult hemorrhage, CSF pressure measurements, myelography, and intrathecal injection of medication
- Contraindications include elevated intracranial pressure, anticoagulation or other bleeding diathesis, and epidural abscess

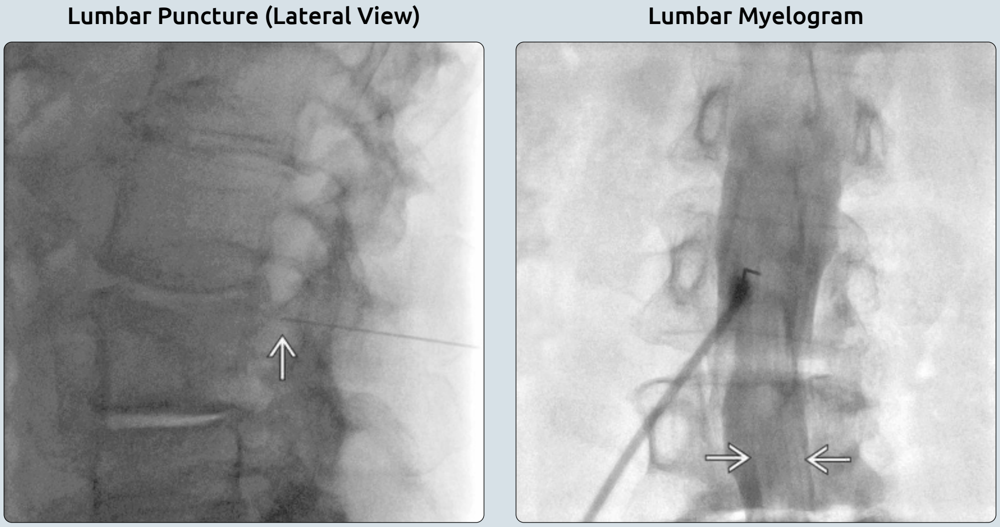
PROCEDURE

- Lumbar puncture
  - Patient in prone positioning targeting L2-L3 or L3-L4 interlaminar/interspinous space
  - Insert 20- to 22-g spinal needle (3.5" standard) into soft tissues parallel to fluoroscopic beam with needle directed to interlaminar space
  - Advance needle slowly through soft tissues until reaching lack of resistance (signals thecal sac entrance)
  - CSF should flow passively into collection tubes
- Myelogram
  - Initial injection must see contrast free-flowing
- Epidural blood patch
  - Insert spinal needle using similar technique as lumbar puncture; however, needle tip should terminate in dorsal epidural space
  - Draw 15-20 mL of fresh, nonclotted blood from patient's IV and inject into epidural space


Lumbar Puncture (Graphic)

Lumbar Puncture (Slight AP Obliquity)

(Left) *Sagittal graphic demonstrates ideal positioning of spinal needle during lumbar puncture. The needle tip is within the thecal sac and well below the conus terminalis.* **(Right)** *Coned-down near-AP fluoroscopic image of the lumbar spine demonstrates a spinal needle with tip overlying the right L2-L3 interlaminar space* ➡.


Lumbar Puncture (Lateral View)

Lumbar Myelogram

(Left) *Coned-down lateral fluoroscopic image demonstrates a spinal needle terminating within the central spinal canal* ➡. *Return of clear fluid from the spinal needle confirmed intrathecal placement. Lateral views are helpful for determining needle depth in complicated cases.* **(Right)** *Fluoroscopic image obtained during a lumbar myelogram demonstrates injection of iodinated contrast into the thecal sac. Contrast should flow freely away from the needle tip and the cauda equina nerve roots should be visualized* ➡.

TERMINOLOGY

Synonyms

- Spinal tap

Definitions

- Lumbar puncture: Insertion of spinal needle into thecal sac for diagnostic retrieval of CSF &/or injection of therapeutic or other diagnostic material
- Myelogram: Lumbar puncture with injection of myelography-safe iodinated contrast into thecal sac to visualize spinal canal, spinal cord and nerve roots
- Epidural blood patch: Autologous blood injection into epidural space to treat spinal leak from prior dural puncture

PREPROCEDURE

Indications

- Lumbar puncture
  - Suspected meningitis
  - Occult subarachnoid hemorrhage
    - For subacute/chronic hemorrhage, CSF will be positive for xanthochromia from hemoglobin breakdown
  - CSF pressure measurement
    - Idiopathic intracranial hypertension (a.k.a. pseudotumor cerebri)
    - Normal pressure hydrocephalus
  - Inflammatory or neoplastic assessment of CSF
    - Multiple sclerosis
    - Guillain-Barré syndrome
  - Injection of intrathecal chemotherapy or radioisotope
- Myelography
  - Evaluate spinal canal and nerve roots in patients with contraindication to MR
  - Characterize vertebra in degenerative disc disease
  - Localize CSF leak: Utilizing CT after myelography can localize CSF leak at skull base
- Epidural blood patch
  - Spinal headache and CSF leak following lumbar puncture
    - Typically headache is orthostatic, worsening with standing and improving with lying flat

Contraindications

- Elevated intracranial pressure
- Noncommunicating hydrocephalus
- Anticoagulation or other bleeding diathesis
  - Warfarin: Withhold 4-5 days prior to procedure
  - Direct-acting novel oral anticoagulants: Withhold 48-72 hours depending on GFR
  - Low molecular weight heparin
    - Therapeutic (high) dose: Should be withheld 24 hours before and after procedure
    - Prophylactic (low) dose: Should be withheld 12 hours before and 24 hours after procedure
  - Unfractionated heparin
    - IV heparin: Should be withheld 2-4 hours before and at least 1 hour after procedure
    - SC heparin: No contraindication if < 10,000 units administered
  - Antiplatelet therapy stronger than ASA
  - Thrombocytopenia: No specific guidelines exist but platelets should generally be above 50,000/μL
- Spinal epidural abscess
- Allergy to iodinated contrast (for myelography)

Preprocedure Imaging

- MR or CT of brain
  - Recommended to exclude any intracranial process or mass causing elevated intracranial pressures, which would put patient at risk for tonsillar herniation following lumbar puncture
- Prior MR or CT myelogram of spine
  - Knowing level of conus terminalis &/or areas of high-grade spinal stenosis helps guide level of access

Getting Started

- Things to check
  - Clinical history and indication
  - Informed consent
  - Allergies (contrast, lidocaine, sedation)
  - Medications (anticoagulants, antiplatelet drugs)
  - Laboratory parameters
    - Coagulation factors: INR < 1.5 (LP performed above this value requires close neurological follow up)
    - CBC: Platelets > 50,000/μL
- Medications
  - Myelography-safe contrast: Nonionic low osmolality contrast, (e.g., Isovue M 200 or 300)
  - Local anesthetic: Lidocaine

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Prone
    - Angle C-arm slightly lateral of midline & caudal to better visualize interlaminar space
      - ☐ Roll patient slightly oblique by extending patient's knee laterally if fluoroscopy is stationary
    - Typically L2-L3 or L3-L4 interlaminar/interspinous space is utilized to gain access to thecal sac
      - ☐ Prior spinal imaging should be reviewed to determine level of conus terminalis

Procedure Steps

- Lumbar puncture
  - Determine appropriate level of access (typically L2-L3 or L3-L4) and mark skin
  - Sterile preparation and draping of patient
    - Use Betadine if no allergy
    - Some controversy as to whether chlorhexidine used for skin prep can potentially cause arachnoiditis
  - Place radiopaque sterile marker on skin to target interlaminar space
    - Drawing needle may be used as marker
    - Adjust C-arm to open up targeted space
    - Collimation should be optimized to improve contrast of image
  - Inject local anesthetic within cutaneous & subcutaneous tissues along projected path of spinal needle
    - Do not inject anesthetic into thecal sac

  - Insert 20- to 22-g spinal needle (3.5" standard) into soft tissues parallel to fluoroscopic beam with needle directed to interlaminar space
    - Advance needle slowly through soft tissues until reaching lack of resistance (signals thecal sac entrance)
    - Rotate C-arm 90° to confirm needle depth in complicated cases, e.g., morbid obesity & scoliosis
  - Remove stylet from spinal needle, confirm return of CSF
  - If performing opening pressure, roll patient onto their side with legs outstretched; take pressure with manometer prior to collection
  - Collect CSF within labeled specimen tubes
    - CSF should flow passively into collection tubes
    - Tilt table in reverse Trendelenburg to increase flow
    - Aspiration **not** recommended: Increased risk of bleeding, suction of cauda equina nerve roots
  - Reinsert stylet, remove spinal needle, and apply bandage
- Myelogram
  - Lumbar puncture as above
  - Attach tubing and inject 12-14 mL of myelographic contrast
    - Initial injection must see contrast free-flowing in thecal sac
      - Clumping of contrast around needle tip means needle is epidural & should be repositioned
  - Once contrast injected, replace stylet & remove needle
  - Obtain spot fluorographic images of indicated region of spine (cervical, thoracic, lumbar) including AP, lateral, and oblique projections
    - Rolling patient 360° helps mix CSF and contrast
  - Movement of contrast to level of interest can be facilitated by tilting fluoroscopy table
- Epidural blood patch
  - Sterile technique is imperative to prevent injection of contaminated blood and risk of epidural abscess
  - Insert Tuohe needle using similar technique as lumbar puncture; however, needle tip should terminate in dorsal epidural space
    - Loss of resistance technique
      - 5 mL of air or saline drawn into syringe and attached to spinal needle
      - As needle advanced through soft tissues, apply light injection pressure to syringe
      - Significant loss of resistance will be noted upon entering epidural space
  - Inject 2 mL of iodinated contrast to ensure appropriate location in epidural space
  - Draw 15-20 mL of fresh, nonclotted blood from patient's IV and inject into epidural space
    - Injection should be terminated if patient experiences increasing back pain

Findings and Reporting

- Indicate vertebral level of access to spinal canal
- Record opening pressure if obtained (normal 10-24 cm water)
- Record color/appearance and amount of CSF removed
- Document amount and type of contrast administered
- Post myelogram images
  - Confirm level of conus if not already known and characterize any abnormality to cauda equina nerve roots (thickening, clumping, empty thecal sac)
  - Comment on spinal canal stenosis or effacement of nerve root sheaths
  - Specify area of CSF leak if seen

POST PROCEDURE

Things To Do

- Escort patient to CT scanner for post myelogram imaging
- Keep patient hydrated and lay flat for 2-4 hours
- Close neurological follow up if abnormal coagulation

Things To Avoid

- Driving should be avoided post myelogram due to potential lower threshold for seizures

OUTCOMES

Problems

- Postprocedural spinal headache
- Back pain ± radiculopathy

Complications

- Most feared complication(s)
  - Lumbar puncture
    - Uncal or tonsillar herniation
    - Hematoma (subarachnoid, subdural or epidural)
    - CSF leak (more frequent when using needles > 20-g)
  - Myelogram
    - Seizure or other contrast reaction
      - Medications which lower seizure threshold should be held before and after myelography due to potential increased risk of seizure activity
    - Injection of nonmyelographic contrast or other noncontrast syringe on tray (lidocaine)
  - Epidural blood patch
    - Epidural abscess from contaminated blood products
    - Arachnoiditis from intrathecal injection of blood
- Delayed complication(s)
  - Persistent headaches after several days: CSF leak
    - CSF leak is relatively uncommon following LP due to small size of spinal needle
    - Refractory CSF leak can be treated with epidural blood patch
  - Epidural abscess

Expected Outcomes

- Epidural blood patch success rates
  - 1st attempt: 75% complete relief of symptoms, 18% partial relief, and 7% failure
  - 2nd attempt: 53% complete relief of symptoms, 37% partial relief, and 10% failure
- Spinal headache rates up to 35%: Lying flat, consuming caffeine and salt can help resolve headaches

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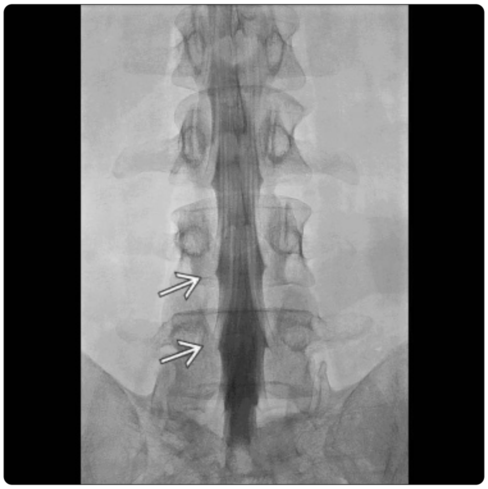
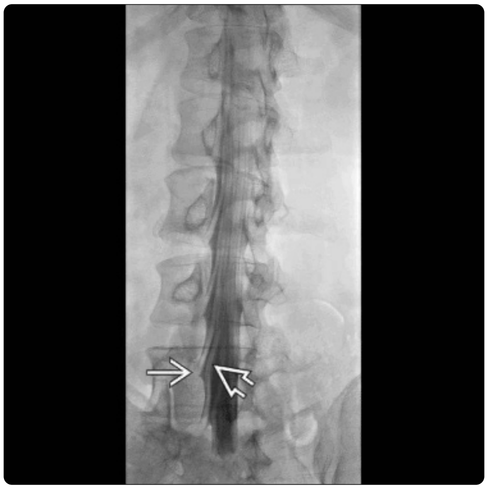
1. Ning S et al: Safety of lumbar punctures in patients with thrombocytopenia. Vox Sang. 110(4):393-400, 2016
2. Migdal VL et al: Risk-benefit analysis of lumbar puncture to evaluate for nontraumatic subarachnoid hemorrhage in adult ED patients. Am J Emerg Med. 33(11):1597-601, 2015

AP Myelogram

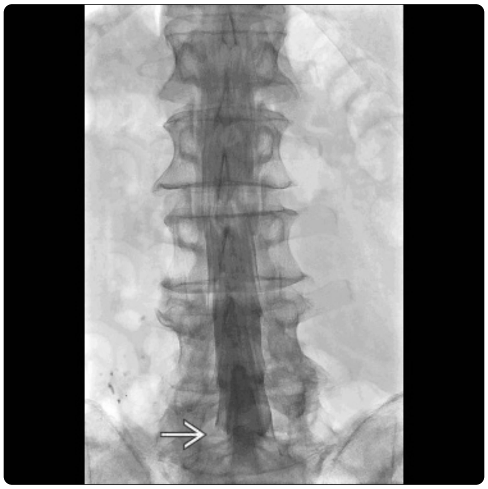


Myelogram LAO Projection

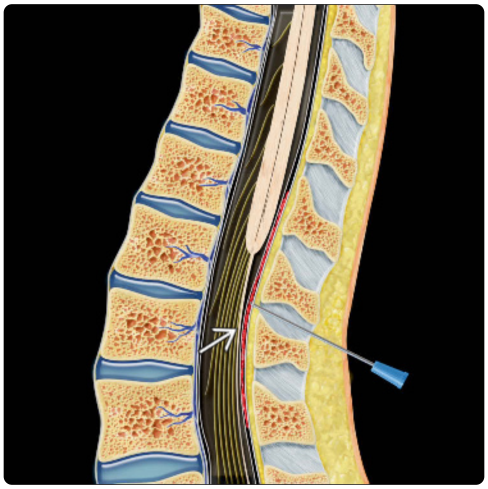


(Left) *Anteroposterior imaging during a myelogram demonstrates contrast filling the thecal sac. The nerve root sleeves* ➡ *are visualized containing the exiting cauda equina nerves, which are numbered according to the vertebral level above.* **(Right)** *An oblique myelogram shows the left nerve root sleeves* ➡ *and nerves coursing within the lateral recesses* ➡*. In the setting of disc herniation, these areas may become effaced from compression.*

Myelogram With Disc Herniation

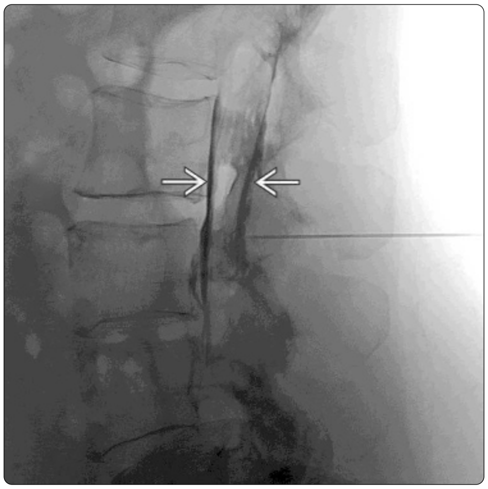


Epidural Blood Patch (Graphic)

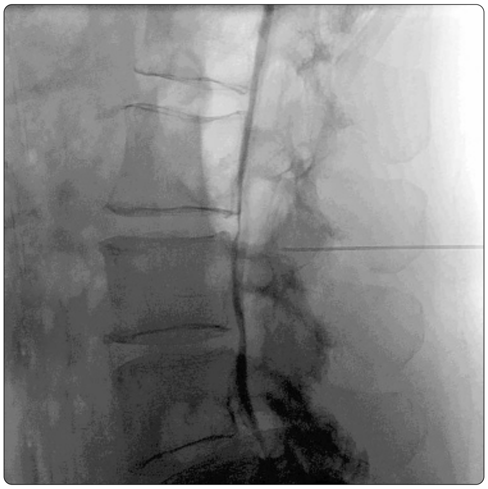


(Left) *An anteroposterior view during a myelogram demonstrates a left paracentral disc herniation/protrusion at L5-S1 with effacement of the left L5 nerve root sleeve* ➡*.* **(Right)** *A sagittal graphic of an epidural blood patch demonstrates ideal positioning of the spinal needle within the dorsal epidural space with injection of autologous blood products* ➡*.*

Epidural Blood Patch (Contrast Injection)



Epidural Blood Patch (Autologous Blood Injection)



(Left) *An initial fluoroscopic image after injection of a small amount of iodinated contrast confirms needle position within the epidural space with contrast surrounding the thecal sac* ➡*.* **(Right)** *A repeat fluoroscopic image in the same patient following the administration of blood products demonstrates the contrast flowing away from the needle tip, again confirming location in the epidural space.*

Vertebral Augmentation and Sacroplasty

KEY FACTS

TERMINOLOGY

- **Vertebroplasty**: Percutaneous vertebral body augmentation with acrylic cement injection
- **Kyphoplasty**: Percutaneous vertebral body augmentation using balloon catheter to create space within vertebra prior to acrylic cement injection
- **Sacroplasty**: Percutaneous injection of acrylic cement into one or both sacral ala(e) for relief of pain caused by sacral insufficiency fracture(s)

PREPROCEDURE

- **Procedure indications**
  - Painful acute/subacute vertebral compression fracture or sacral fracture; refractory to medical therapy
  - Neoplastic VCFs or sacral fractures

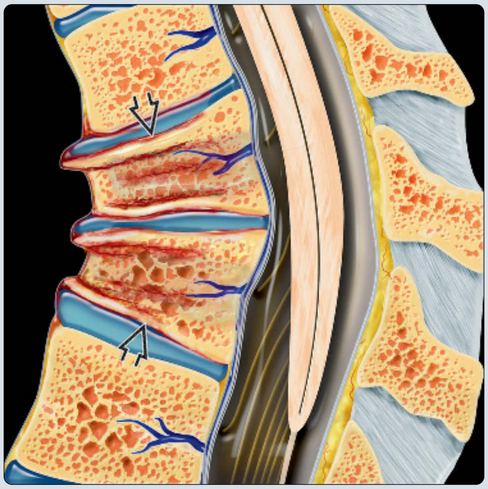
PROCEDURE

- Vertebroplasty
  - Localize vertebra to be treated; give local anesthesia
  - Introduce vertebroplasty trocar-cannula (needle)
    - Transpedicular needle route safest
    - Advance needle into vertebral body
  - Slowly inject cement into vertebral body; monitor with fluoroscopy and avoid extravasation
- Sacroplasty
  - Utilize CT guidance for initial placement of trocar-cannula into fracture site
    - Some advocate fluoroscopy-guided needle placement
  - Inject cement utilizing fluoroscopy, CT-fluoro, or intermittent CT imaging to monitor for extravasation

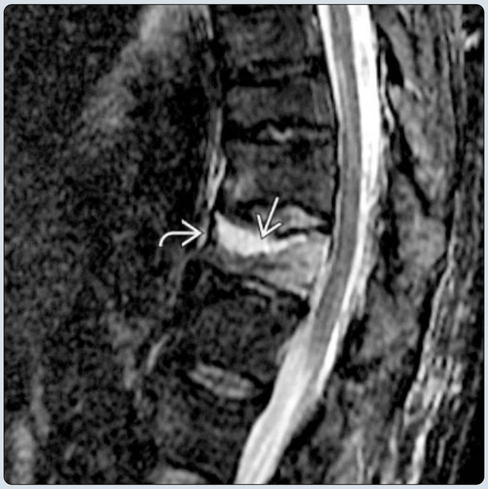
OUTCOMES

- Complications: 1-10% (< 2.5% for benign disease)
  - Damage to nerves/vessels/spinal cord (paralysis)
  - Infection, bleeding, fracture, pneumothorax
  - Acrylic leakage into epidural/paravertebral veins, neural/sacral foramina, or spinal canal

Vertebral Body Compression (Graphic)

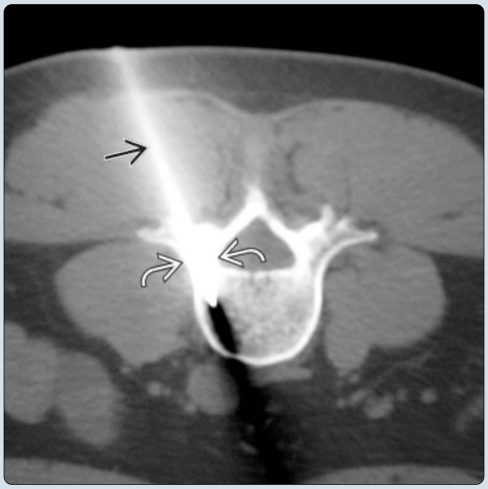


Vertebral Body Compression (MR)

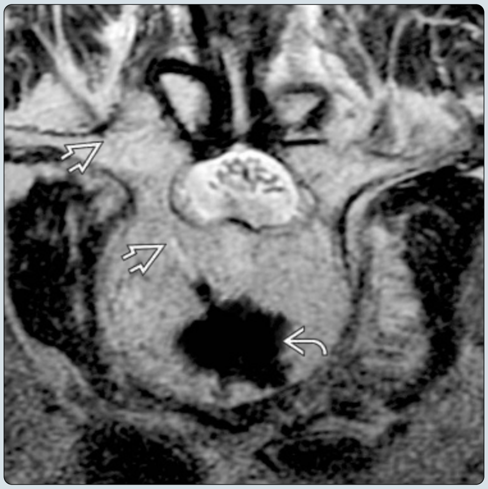


(Left) *A sagittal graphic shows adjacent acute vertebral body compression fractures ⇨. With multiple fractures in an osteoporotic patient, other issues such as pulmonary compromise may ensue if further collapse occurs.* **(Right)** *Sagittal T2 FS MR imaging demonstrates a compression fracture ↪ of a lower thoracic spine vertebra. The increased signal → in the vertebral body reflects edema and indicates that this is an acute to subacute fracture. There is no associated narrowing of the spinal canal.*

Vertebroplasty (Transpedicular Needle Trajectory)



Vertebroplasty (Postprocedure MR)



(Left) *During transpedicular approach, the coaxial needle → traverses the cortical confines of the pedicle ↪ and advances to the anterior 1/3 of the vertebral body. CT guidance is not routinely used for vertebroplasty.* **(Right)** *Axial T2 MR imaging after vertebroplasty shows a signal void ↪ anteriorly in the vertebral body, corresponding to the cement that was injected during the procedure. A linear ⇨ area of signal coursing through the pedicle reflects the transpedicular needle tract.*

TERMINOLOGY

Definitions

- **Vertebroplasty**: Percutaneous vertebral body augmentation with acrylic cement injection
  - Main goal: Pain relief for patients who fail conservative treatment
  - Stabilize vertebral body height preventing further kyphotic spinal angulation
- **Kyphoplasty**: Percutaneous vertebral body augmentation using balloon catheter to create space within vertebra prior to acrylic cement injection
  - Same advantages as vertebroplasty
    - Potential for height restoration
    - Lower rate of acrylic leakage into adjacent tissues
- **Sacroplasty**: Percutaneous injection of acrylic cement into one or both sacral ala(e) for relief of pain caused by pathologic or insufficiency fracture

PREPROCEDURE

Indications

- Painful acute/subacute vertebral compression fracture (VCF) or sacral insufficiency fracture refractory to conservative therapy
  - Minimal to no pain relief following prescription analgesic administration
    - Unspecified time period, although some suggest at least 4 weeks of medical management before intervention attempted
  - Patients unable to ambulate because of pain
  - Painful VCF due to osteonecrosis (Kümmell disease)
  - Unstable VCF
    - Demonstrates movement at wedge deformity
  - Multiple compression deformities, with associated risks if further collapse
    - Pulmonary compromise
    - Gastrointestinal dysfunction
  - Altered center of gravity
    - Affects gait stability
- VCFs or sacral fractures associated with neoplastic disease
  - Significant focal pain unresponsive to analgesia
    - Further considerations
      - ☐ Local/general extent of disease
      - ☐ Patient's medical condition/general health
      - ☐ Response to previous therapy
      - ☐ Patient life expectancy
- Traumatic VCF
  - Effective method of achieving multiple benefits
    - Decreased pain
    - Increased mobility
    - Decreased narcotic usage

Contraindications

- Chronic fractures (variable relief)
- Prophylactic vertebroplasty
  - Osteopenic patient with no acute fracture
- Asymptomatic stable fractures; improving pain
- Uncorrectable coagulopathy
- Elevated WBC count (unless due to steroid use)
  - Systemic infection, fever, osteomyelitis
- Significant spinal canal compromise
  - Retropulsed fragments, vertebra plana
  - Risk of worsening spinal canal compromise
    - Unstable posterior vertebral body wall
  - Vertebroplasty use in treating burst fractures
    - Only when conservative management has failed
    - Medical condition justifies vertebroplasty
  - Neoplastic disease with large soft tissue component extending into spinal canal or neural/sacral foramen
- Radiculopathy unrelated to fracture (e.g., disc disease)
- Significant destruction/collapse; height loss ≥ 70%
  - Relative contraindication for neoplastic VCF

Preprocedure Imaging

- Conventional radiographs
  - Osteoporotic postmenopausal females with documented new/subacute fracture
    - Further imaging may not be required
    - ± intravertebral gas-filled clefts
      - ☐ Vertebral pseudarthrosis seen in Kümmell disease
- Indications for obtaining CT or MR
  - Patient with single/multiple fractures of uncertain age without serial conventional radiographs
  - Pathologic fractures
    - MR typically better for disease extent
      - ☐ Location/number of involved vertebrae
      - ☐ Spinal canal/neural compromise
    - CT typically better for bone detail
      - ☐ Degree of bone destruction
      - ☐ Cortical involvement, displaced fragments
- MR
  - Determine acuity vs. chronicity of fracture
  - Acute/subacute VCFs and sacral fractures
    - Decreased T1 signal
    - Hyperintensity on T2 or STIR (edema)
    - May visualize fracture cleft
  - Results following vertebral augmentation better for fractures with bone marrow edema
    - Poor bone marrow integrity predicts subsequent refracture of augmented vertebra
- Radionuclide bone scan (Tc-99m MDP)
  - More sensitive than MR in detecting active fractures, but not as specific
    - Typically used if MR not possible
    - SPECT may be necessary to determine level
  - Usually positive in 1st 3-4 months of fracture
  - Sacral fractures: Honda sign of acute/subacute bilateral sacral ala fractures resembles capital letter H

Getting Started

- Things to check
  - Clinical history/physical examination
    - General medical condition
    - Specifics regarding back pain, mobility
      - ☐ Radicular symptoms; neurological deficits
      - ☐ Sites of point tenderness to percussion/palpation and positional "trigger points"
      - ☐ Ability to lie prone without compromise
    - Procedural/sedation informed consent
  - Allergies

  - Current medications
    - Analgesics, steroids, bisphosphonates, calcitonin, hormone replacement therapy (HRT)
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
    - Complete blood count (CBC)
      - Platelet count > 50,000/μL
    - Coagulation profile
      - International normalized ratio (INR) ≤ 1.5
      - Normal prothrombin time (PT), partial thromboplastin time (PTT)
  - Consent: Risks include nerve injury, cord compression, paralysis, infection, lack of relief in older subacute fractures
- Medications
  - Stop oral anticoagulants 5 days prior to procedure
    - Bridge with low molecular heparin, if necessary
  - Ancef 1 g or clindamycin 600 mg IV before procedure
- Equipment list
  - Fluoroscopic suite (monoplane/biplane) or C-arm
  - CT occasionally may be used for very difficult cases
  - Polymethylmethacrylate (PMMA) cement
    - Consists of 2 components
      - Fine-grained powdered polymer
      - Volatile liquid monomer
    - Polymerization time (curing rate) variable
      - Depends on product
      - Slurry injectable for 5-20 min; prolonged by refrigerating kit prior to use
    - Factors affecting visualization
      - Patient size; imaging quality
      - Amount of barium sulfate within product
      - Location of target vertebral body
    - 1 mL Luer lock syringe/commercial cement delivery system
      - Used for injection of acrylic slurry
    - Vertebroplasty trocar stylet and cannula
      - 11- to 13-g needle (thoracic/lumbar procedures)
      - 15-g needle (cervical spine)
      - AVAflex curved needle (CareFusion; San Diego, CA)
    - Kyphoplasty materials
      - 11-g needle (diamond/bevel tip stylets)
      - Kyphoplasty balloon
      - Calibrated inflation device

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Position patient prone
    - Chronic obstructive pulmonary disease/asthma patient may have breathing difficulty if prone; anesthesia-managed sedation may be needed
    - Toradol IV can decrease pain for positioning; caution with renal insufficiency patients
  - Fluoroscopically localize treatment level, confirm level with available diagnostic images
  - Align superior/inferior endplates of vertebra, angle fluoroscopy craniocaudal as needed
  - Localize pedicle and plan approach
  - **Transpedicular vs. parapedicular approach**
    - Transpedicular
      - Detector angle affects access success
      - No intervening structures that may be damaged
      - Difficult in cervical spine
      - Transpedicular route safe
    - Parapedicular
      - Needle tip advanced lateral to lateral pedicular cortex
      - Allows steep needle trajectory, permitting more medial needle tip position
      - Allows access if small pedicle
      - Parapedicular route slightly less safe (e.g., pneumothorax/paraspinal hematoma risk)
  - **Fluoroscopic detector position**
    - Ipsilateral fluoroscopy position
      - Rotate detector 20° ipsilateral to pedicle; places medial pedicle cortex at middle 1/3 of vertebra
      - Pedicle should appear ovoid/round
      - Center needle in circle formed by pedicle cortex (needle will be seen end-on); make skin nick
      - Maintain end-on appearance while advancing needle; always centered in pedicle
      - Results in steep lateral to medial needle track, and final needle position in vertebral body midline
    - Anteroposterior fluoroscopy position
      - Center spinous process at vertebral body
      - Make skin nick slightly superior and lateral of pedicle, further lateral at caudal levels
      - Advance needle, contact bone at superior-lateral aspect of pedicle
      - Advance needle through pedicle
      - Do **not** cross medial aspect of pedicle until needle anterior of thecal space in sagittal view
      - Once needle tip is anterior of posterior vertebral body cortex, it may cross medial of pedicle
  - Confirm planned craniocaudal trajectory of needle in sagittal view regardless of approach and gantry angle

Procedure Steps

- **Vertebroplasty**
  - Use conscious sedation during procedure
  - Administer local anesthesia with 1% lidocaine
    - Avoid use of vasoconstrictor (e.g., epinephrine)
    - Use long 25-g spinal needle permitting anesthesia of periosteum
  - Make paravertebral incision with #11 scalpel
  - Introduce vertebroplasty trocar-cannula (needle)
    - Confirm needle location when bone contacted
    - Be certain there is adequate needle angulation
  - Advance needle into vertebral body
    - May need mallet to advance needle in nonosteoporotic patients
    - Diamond-point stylet of needle optimal for initial needle positioning into pedicle
      - Beveled stylets tend to slip off pedicle
      - Once tract is started, repositioning is difficult
    - Single-beveled stylet deflects needle in direction opposite bevel
      - Allows minor adjustments in either plane once needle inside vertebral body

  - Fluoroscopically monitor needle position and progression in AP/oblique and sagittal views
    - Continuous monitoring possible with biplane, intermittent with single plane
    - Stop advancing when stylet tip is in anterior 1/3 to 1/4 of vertebral body
    - Determine whether needle tip position optimal
      - Consider need to advance curved cannula: Flexible curved nitinol needle with sideport allowing targeted cement placement
      - Consider placing 2nd (contralateral) needle
  - Mix cement (start timer)
    - Thick cement safer than more liquid consistency
  - Load vertebroplasty syringes with cement
  - Remove trocar stylet from cannula
  - Connect vertebroplasty syringe to cannula
  - Slowly inject cement into vertebral body
    - Monitor with fluoroscopy, primarily sagittal
  - Cement must **not** extravasate into central canal
    - Caution with high-pressure cement injection
  - Avoid extravasation into disc space
  - Fill 50-70% residual volume of compressed vertebra
  - Replace trocar, remove cannula after adequate filling
    - Cement may advance while replacing trocar
    - Rotate cannula to break any adherent cement
  - Apply manual compression over needle sites
- **Kyphoplasty**
  - Similar initial steps to vertebroplasty
    - Position needle stylet same as for vertebroplasty
    - Steps differ after needle insertion/stylet removal
    - Pull back cannula to posterior aspect of vertebra
      - Allows insertion of kyphoplasty balloon
  - Insert kyphoplasty balloon through cannula
  - Inflate kyphoplasty balloon
    - Use iodinated contrast
    - Use inflation syringe with manometer
    - Know inflation parameters
      - Maximal pressure/maximal balloon volume
      - Monitor for correction of kyphotic deformity
  - Deflate kyphoplasty balloon and remove
    - Cavity created by balloon allows cement injection
      - Cement more viscous than with vertebroplasty
  - Connect syringe to cannula
  - Slowly inject cement; fluoroscopically monitor
    - Avoid extravasation into disc space/central canal
      - Stop injection if any leakage seen
- **Expandable vertebral devices**
  - Kiva VCF System
  - Similar initial steps to vertebroplasty
    - Use same trocar trajectory as for vertebroplasty
    - After needle tip reaches mid vertebral body, remove stylet and insert deployment cannula
  - Nitinol guidewire coil advanced from cannula into cancellous bone of vertebral body
  - Medical polymer implant advanced completely over coil, and coil and device withdrawn
    - Implant may restore vertebral body height
  - Connect syringe to cannula
  - Slowly inject cement; fluoroscopically monitor
    - Avoid extravasation into disc space/central canal
      - Stop injection if any leakage seen
  - Recent trials show similar risk of cement extravasation as kyphoplasty, but with less procedure time and few associated fractures
- **Sacroplasty**
  - Initial steps are performed using CT guidance
    - Localize sacral fracture(s) and appropriate access point with CT guidance
    - Target fracture cleft if visible
  - Determine needle access trajectory
    - Longitudinal
      - Long-axis of sacrum with needle tracking along fracture line
      - Fluoroscopic guidance, or CT (steep craniocaudal)
    - Horizontal
      - Short-axis (perpendicular) of sacrum
      - May require > 2 needles
  - Mark overlying skin and place sterile draping
  - Administer local anesthetic to skin, subcutaneous tissue, and bone periosteum
    - Repeat CT with anesthetic needle inserted to ensure appropriate positioning
  - Make small skin incision with scalpel
  - Insert access needle (11-13 g) and advance until reaching bone periosteum
    - Secure needle tip firmly in periosteum
    - Scan to ensure proper position/angulation of needle
  - Advance needle lateral to sacral foramen until reaching targeted region within sacral ala
    - Typically lateral and superior angulation necessary with longitudinal access
    - Monitor needle advancement with CT-fluoroscopy or step-wise CT imaging
  - When needle in appropriate position, prepare for cement injection (similar technique as vertebroplasty)
  - Inject cement
    - Monitor for cement extravasation into sacral foramen, spinal canal, sacroiliac joint, or venous plexus
    - Intermittent CT: Inject 0.5-2 cc cement per side between imaging
    - CT-fluoroscopy: Can monitor during injection with high degree of confidence, but high radiation dose to patient and operator
    - Fluoroscopy: Requires transfer patient to fluoroscopy suite; Lateral view with bi-plane fluoroscopy can monitor presacral or posterior extravasation
  - Withdraw needles during/between cement injections if longitudinal access
  - Typically inject 3-6 cc cement per side
  - Remove needles, image to ensure no cement in soft tissue (may be removed with hemostat if present)
- **Vertebral body biopsy**
  - Access similar to vertebral body augmentation
    - Can be done with fluoroscopic or CT guidance
  - Dedicated core biopsy device introduced through access needle, sample in formalin

POST PROCEDURE

Things to Do

- Bed rest with head of bed flat for 2 hours

  - Transfer to floor/discharge after anesthesia recovery
    - Outpatients: Observe for 2 hours before discharge
- Suggest appropriate reduction of analgesics
  - Focal pain at puncture sites common after procedure; may last up to 48 hours
- Short physical therapy course; possible use of brace
  - Gradually increase activity after lengthy immobilization

Things to Avoid

- Conditions associated with bacteremia
  - May seed spinal column, potentially causing discitis or epidural abscess
- Treatment of > 3 vertebral levels in single session

OUTCOMES

Problems

- Most patients with radicular symptoms respond to
  - Antiinflammatory or narcotic analgesics
  - Local anesthetic infiltration
- Complication rate: 1-10%
  - 1.3% for VCF associated with osteoporosis
  - 2.5% for VCF associated with hemangiomas
  - 10% for VCF associated with neoplastic disease

Complications

- Most feared complication(s)
  - Damage to nerve roots, vessels, and spinal cord
    - Potential for paralysis with spinal cord injury
  - Acrylic in epidural venous plexus/foraminal veins
    - May cause spinal cord/nerve root compression
      - ☐ Resultant radiculopathy/myelopathy
      - ☐ Potentially needs immediate surgery
  - Unsuspected pulmonary embolization of acrylic
    - PMMA can embolize from epidural/paravertebral veins to pulmonary vasculature
      - ☐ Usually without clinical significance
      - ☐ Pulmonary embolus and death reported
  - Aortic/inferior vena cava injury
  - Dural transgression
    - May cause symptomatic cerebrospinal fluid leak
    - Potential for PMMA decompression into thecal sac
- Immediate/periprocedural complication(s)
  - Vertebral body, transverse process, pedicle, or rib fracture
    - Cement leakage into disc space increases risk for adjacent vertebral body fracture
    - Risk factors for refracture of cemented VCF
      - ☐ Larger vertebral body height restoration
      - ☐ Solid lump filling cement
  - Intercostal/lumbar artery injury
    - Can cause bleeding/paravertebral hematoma
- Delayed complication(s)
  - Epidural abscess
  - Ectopic or heterotopic ossification
    - Potential with calcium phosphate injected into vertebral compression fracture
  - Radiation injury

Expected Outcomes

- Pain improvement
  - Early studies controversial on the effectiveness of vertebroplasty and kyphoplasty for pain reduction, although more recent trials have demonstrated improved pain control and quality of life
  - VAPOUR (vertebroplasty for acute painful osteoporotic fractures) trial, 2016
    - Randomized, double-blind, placebo-controlled trial of vertebroplasty
    - Only included fractures < 6 weeks in age
    - Results
      - ☐ Pain reduction at 14 days: Vertebroplasty = 44%, placebo = 21%
      - ☐ Treated patients: Reduced analgesics at 3 & 6 months
      - ☐ Results best thoracolumbar vertebrae (T11-L2)
  - FREE (fracture reduction evaluation) study, 2009
    - Randomized, controlled trial comparing kyphoplasty to conservative management
    - Primary outcome: Based on quality of life
    - Results: Significantly improved quality of life at 1 month with kyphoplasty
  - Buchbinder et al. NEJM, 2009
    - Randomized, double-blind, placebo-controlled trial
    - Placebo group underwent "sham" procedure, which included steps leading up to vertebroplasty but not including insertion of trocar/needle into bone
    - Outcomes showed no difference in pain between groups at 3 months; controversy over methods
      - ☐ Inclusion of fractures up to 1 year old
      - ☐ Use of lidocaine injection into facets/surrounding soft tissue, which may give pain relief
  - Vertebroplasty vs. kyphoplasty: Meta-analysis
    - Similar pain relief
    - Kyphoplasty has lower rates of cement extravasation
    - Kyphoplasty has higher expense
  - Sacroplasty: Multiple retrospective reviews
    - Significant pain relief & improved functional mobility for insufficiency & pathologic fractures
      - ☐ Large-scale controlled trials necessary for further determination

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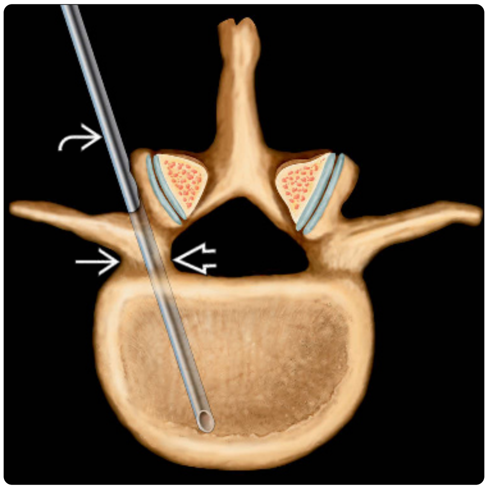
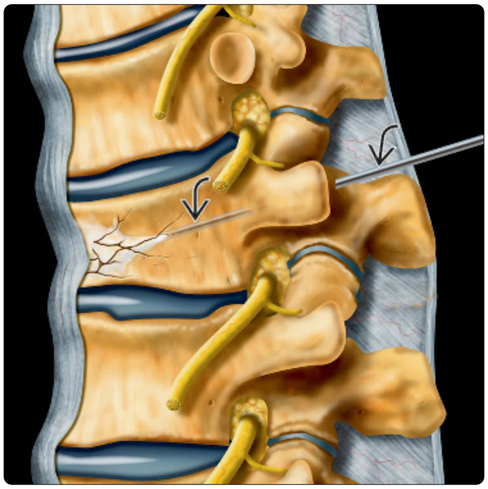
2. El-Fiki M: Vertebroplasty, kyphoplasty, lordoplasty, expandable devices, and current treatment of painful osteoporotic vertebral fractures. World Neurosurg. 91:628-32, 2016
3. Otten LA et al: Comparison of balloon kyphoplasty with the new Kiva® VCF system for the treatment of vertebral compression fractures. Pain Physician. 16(5):E505-12, 2013
4. Zhang JD et al: Comparison of vertebroplasty and kyphoplasty for complications. Orthop Surg. 3(3):158-60, 2011
5. Knavel EM et al: Clinical outcomes with hemivertebral filling during percutaneous vertebroplasty. AJNR Am J Neuroradiol. 30(3):496-9, 2009
6. Wardlaw D et al: Efficacy and safety of balloon kyphoplasty compared with non-surgical care for vertebral compression fracture (FREE): a randomised controlled trial. Lancet. 373(9668):1016-24, 2009
7. Pommersheim W et al: Sacroplasty: a treatment for sacral insufficiency fractures. AJNR Am J Neuroradiol. 24(5):1003-7, 2003

Vertebroplasty Procedure (Transpedicular Needle Trajectory)

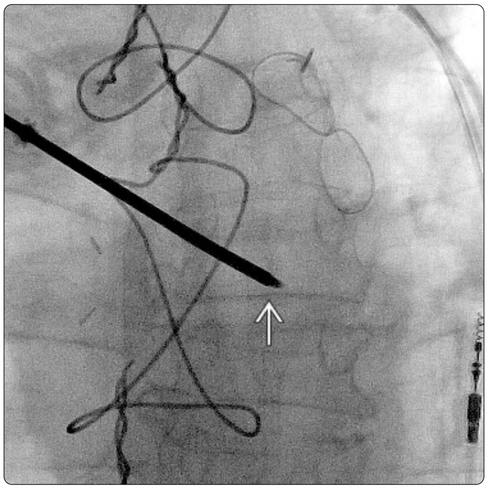


Vertebroplasty Procedure (Transpedicular Needle Placement)

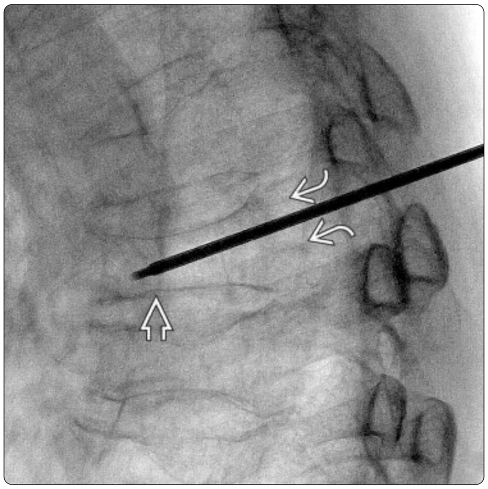


(Left) *Axial graphic shows the trajectory that the vertebroplasty needle should follow for transpedicular access to the vertebral body. The needle ↪ enters the pedicle and courses between the medial ⇨ and lateral → cortical margins.* **(Right)** *Sagittal graphic shows a vertebroplasty needle ↪ that has been introduced into a vertebral body using a transpedicular approach. This is safer than a parapedicular approach, as there are no intervening structures that may be injured.*

Vertebroplasty: Thoracic, Unipedicular (AP Needle Position)

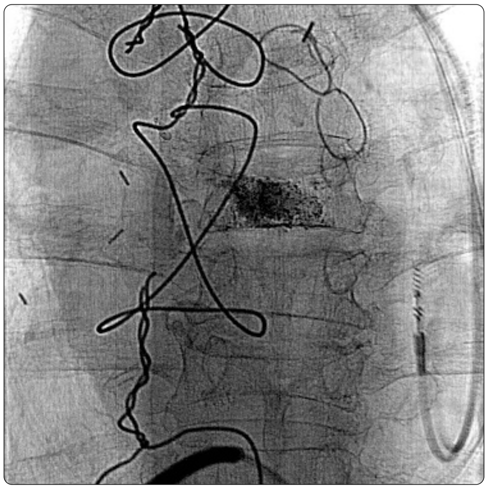


Vertebroplasty: Thoracic, Unipedicular (Sagittal Needle Position)

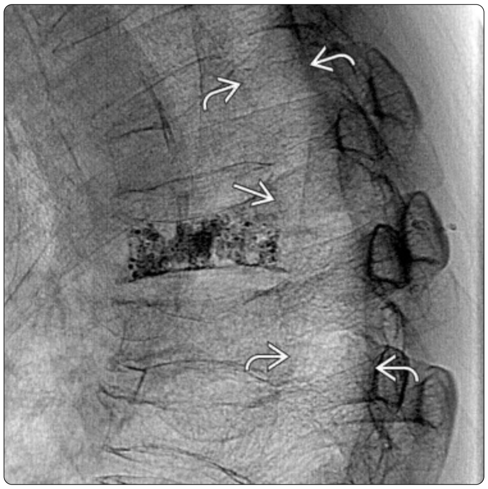


(Left) *MR imaging (not shown) revealed an acute fracture of the thoracic vertebral body accessed in the AP image shown. A 13-g coaxial needle has been advanced to the midline of the vertebral body → (as determined by the location of the spinous process) via right transpedicular approach. This allows cement to fill bilateral aspects of the vertebral body, without necessitating bilateral needle access.* **(Right)** *The needle is advanced to the anterior 1/3 of the vertebral body ⇨, passing within the cortex of the pedicle ↪.*

Vertebroplasty: Thoracic, Unipedicular (AP Post Cement Injection)

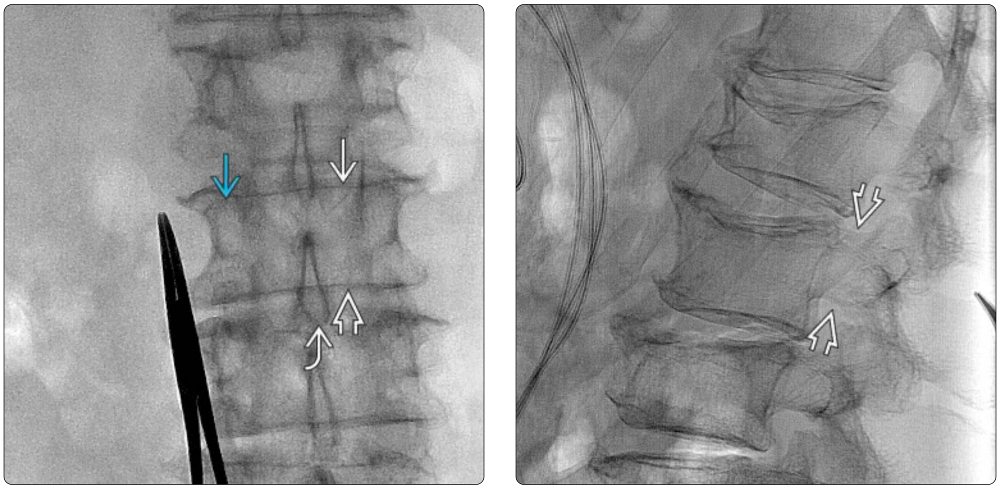


Vertebroplasty: Thoracic, Unipedicular (Sagittal Post Cement Injection)



(Left) *Appropriate cement filling of the vertebral body is shown. Injected cement fills right and left aspects of the vertebral body, and does not track through the endplates or lateral of the vertebral body.* **(Right)** *Most importantly, cement does not track posterior of the vertebral body → where it could narrow the thecal space ↪.*

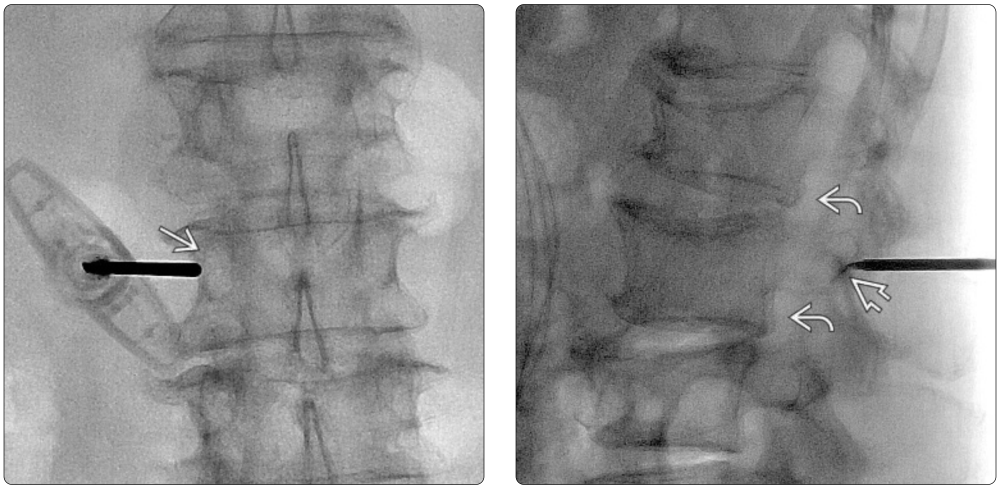
(Left) *Position fluoroscopy to line-up the superior ➡ and inferior ➡ endplates, and center the spinous process ➡. A hemostat marks the skin access site, slightly superior and lateral of the pedicle ➡. This example describes needle placement with AP visualization. Some authors suggest replacing the AP view with an alternate oblique view centered on the pedicle and allowing "down the barrel" visualization.* **(Right)** *In the sagittal plane, the C-arm should be positioned to line-up the pedicles ➡ (and ribs, if visualized).*



Vertebroplasty, Transpedicular Approach (Fluoroscopic Alignment)

Vertebroplasty, Transpedicular Approach (Fluoroscopic Alignment)

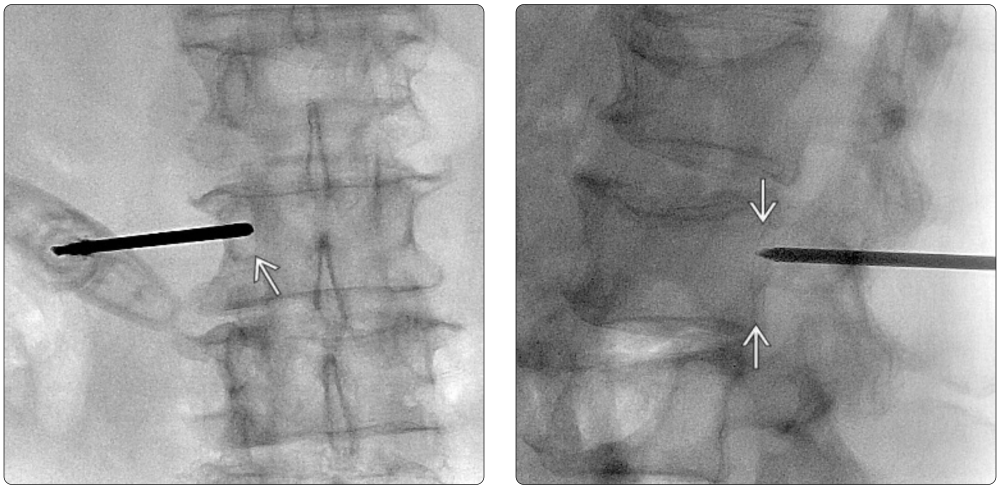
(Left) *An access needle is advanced through the soft tissues until bone is contacted. The needle tip should be located at the lateral edge ➡ of the pedicle at this point.* **(Right)** *In the sagittal plane, the needle is seen contacting the posterior aspect of the vertebral body elements ➡. The needle trajectory is in line to cross through the pedicle and avoid the intervertebral foramen ➡.*



Vertebroplasty, Transpedicular Approach (Advance Needle to Periosteum)

Vertebroplasty, Transpedicular Approach (Advance Needle to Periosteum)

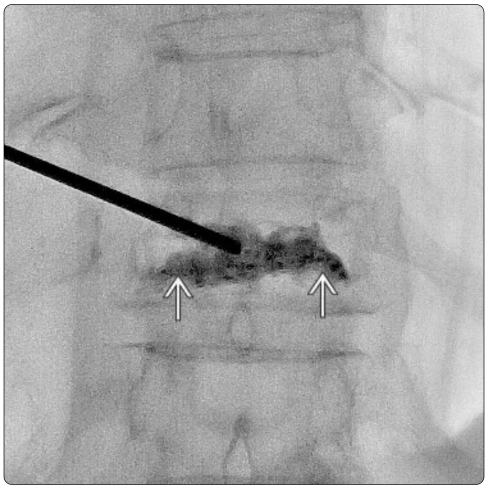
(Left) *As the needle is advanced through the pedicle, it must not cross the medial or inferior aspect of the pedicle ➡. To do so would risk injury to spinal nerves, or to the spinal cord itself depending on the vertebral level accessed.* **(Right)** *The needle tip is now located at the posterior aspect of the vertebral body ➡. The needle must remain lateral of the pedicle's medial border at this point; however, once the needle is anterior of this location, it may safely cross medial to the pedicle since the needle will be anterior of the thecal space.*



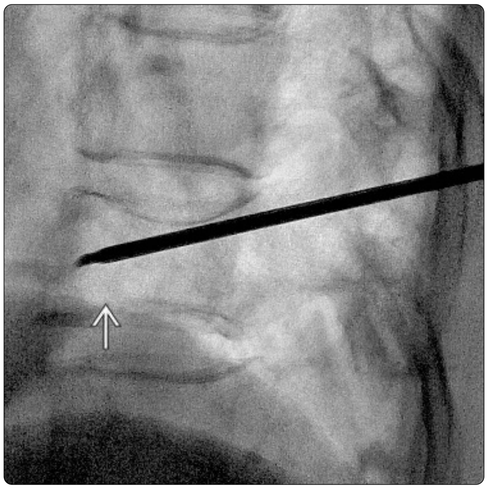
Vertebroplasty, Transpedicular Approach (Advance Needle to Vertebral Body)

Vertebroplasty, Transpedicular Approach (Advance Needle to Vertebral Body)

Vertebroplasty, Transpedicular Approach (Midline Needle Tip Position)

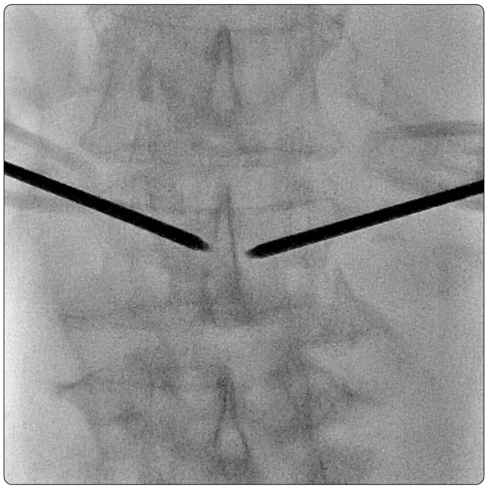


Vertebroplasty, Transpedicular Approach (Midline Needle Tip Position)

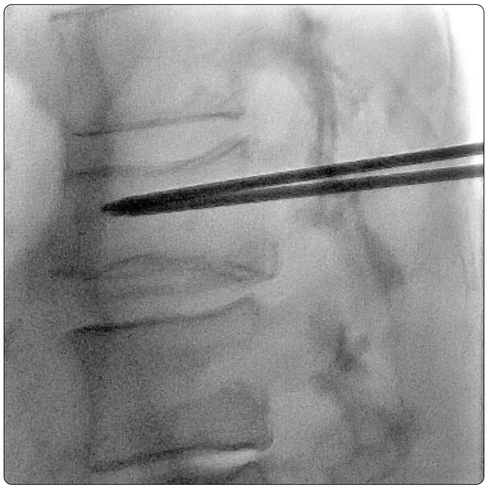


(Left) *In a different patient at thoracic level, the needle is advanced to midline of vertebral body if possible. If needle cannot be advanced to midline, bipedicular access, or use of a curved curette may be considered. Note barium sulfate within cement* ➡, *allowing visualization.* **(Right)** *The needle is positioned within the anterior 1/3 of the vertebral body* ➡ *immediately prior to cement injection. Typically, cement is injected during sagittal visualization, with intermediate AP evaluation between injections.*

Alternate Bipedicular Approach (Proper Needle Position)

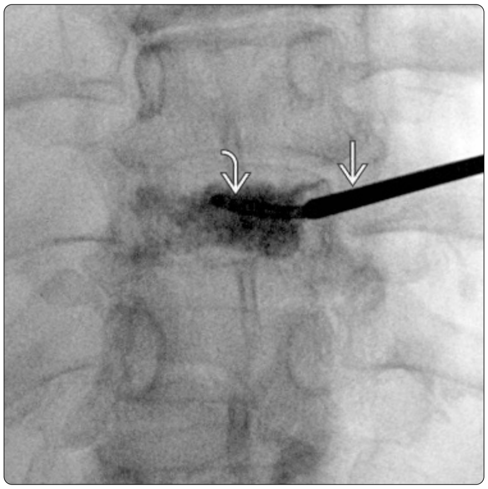


Alternate Bipedicular Approach (Proper Needle Position)

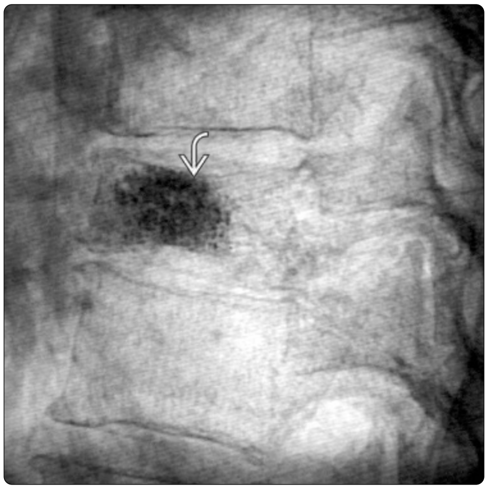


(Left) *Bipedicular needle access is often desirable when treating lumbar vertebra. Unilateral access can lead to asymmetric filling of these larger vertebra.* **(Right)** *Both needles follow a similar path through the pedicle to arrive at the anterior 1/3 of the vertebral body. Cement may now be injected, confident that symmetric filling can be achieved.*

Alternate Curved Curette (Cement Delivery)



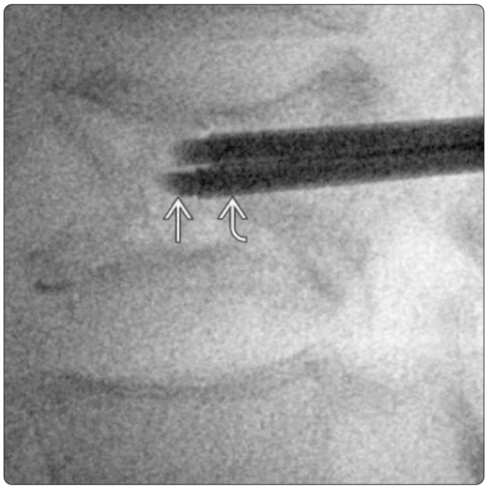
Alternate Curved Curette (Lateral Radiograph)



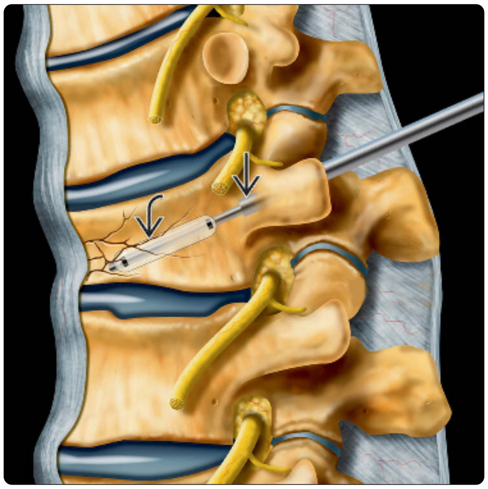
(Left) *Rather than positioning the needle at midline, which risks crossing medially of the pedicle during advancement, the access needle* ➡ *may remain ipsilateral to access. Then, a curved curette* ↪ *is advanced coaxially through the access needle. The curette may be used to make a cavity, or cement may be injected through the curette allowing more accurate cement deposition during vertebroplasty.* **(Right)** *Cement* ↪ *is distributed in the anterior 2/3 of the vertebra, with no evidence of extravasation.*

(Left) *Two kyphoplasty needles have been introduced from bilateral transpedicular approaches. Tracks for kyphoplasty balloon can be created by advancing needle tips* ➡ *to the anterior 1/3 of the vertebral body and then withdrawing the outer cannulas* ➥*, or by advancing metallic drills (included in kit) through the cannulas into the vertebral body.* **(Right)** *After positioning the cannula* ⇨ *in the posterior vertebra and removing the stylet, a deflated kyphoplasty balloon* ↪ *is inserted via the cannula into the anterior vertebral body.*

Kyphoplasty (Initial Needle Placement)

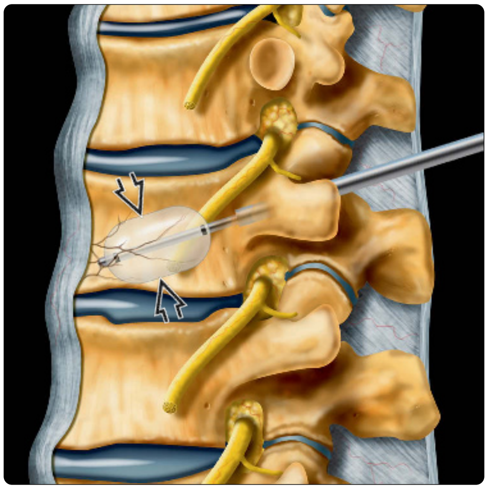


Kyphoplasty (Balloon Insertion)

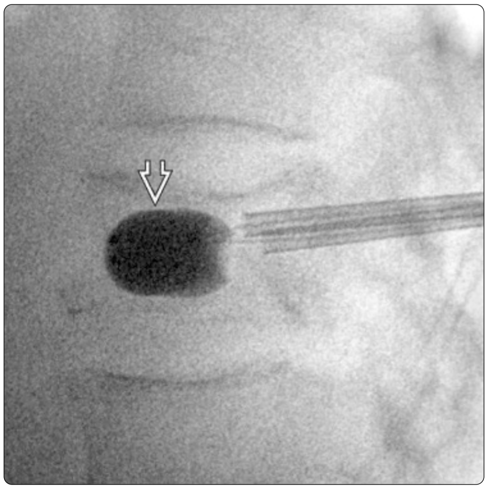


(Left) *The kyphoplasty balloon* ⇨ *is slowly inflated with iodinated contrast material using an inflator with a calibrated manometer. The balloon should be inflated to maximal volume or pressure.* **(Right)** *Lateral fluoroscopic spot radiograph shows a single inflated kyphoplasty balloon* ➥*. The balloon inflation creates a void within the cancellous bone prior to cement delivery and may result in some height restoration to the vertebra.*

Kyphoplasty (Balloon Inflation)

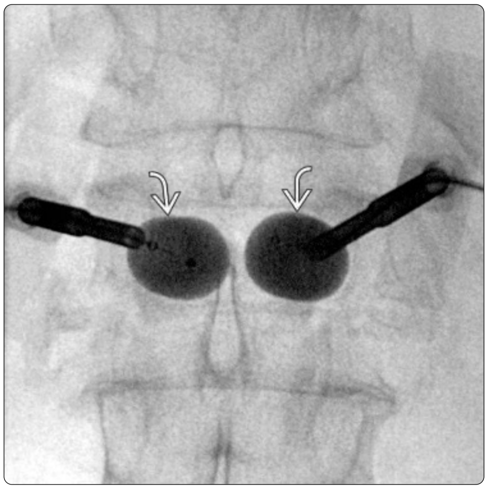


Kyphoplasty (Balloon Inflation)

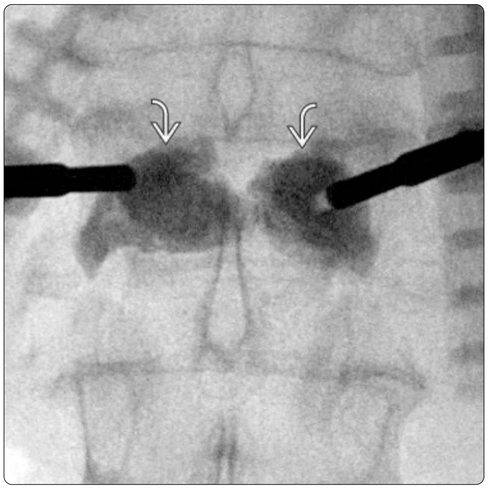


(Left) *Bilateral transpedicular kyphoplasty balloons* ➥ *have been inflated with iodinated contrast. Both unipedicular and bipedicular approaches may be used for kyphoplasty and vertebroplasty.* **(Right)** *The kyphoplasty balloons are deflated and removed, and then PMMA bone cement* ➥ *is injected into the cavities that were created. The cement is delivered slowly through the cannulas, with continuous lateral and AP fluoroscopic monitoring.*

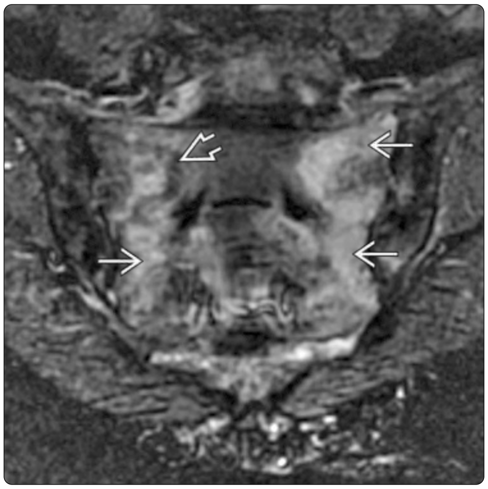
Kyphoplasty (Bipedicular Balloon Inflations)



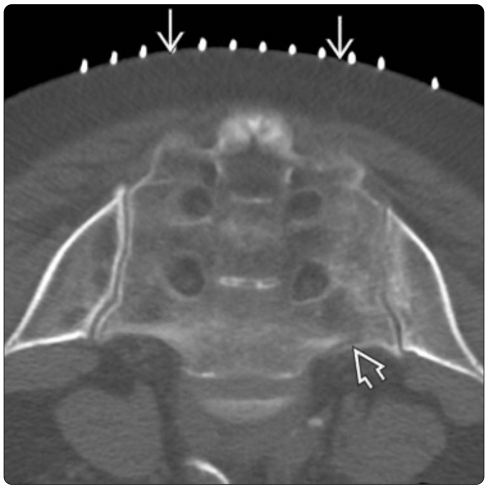
Kyphoplasty (Bipedicular Cement Injection)



Sacroplasty (Sacral Insufficiency Fractures)

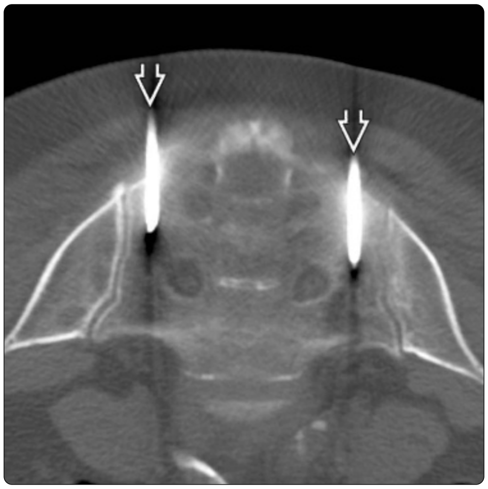


Sacroplasty (Access Localization)

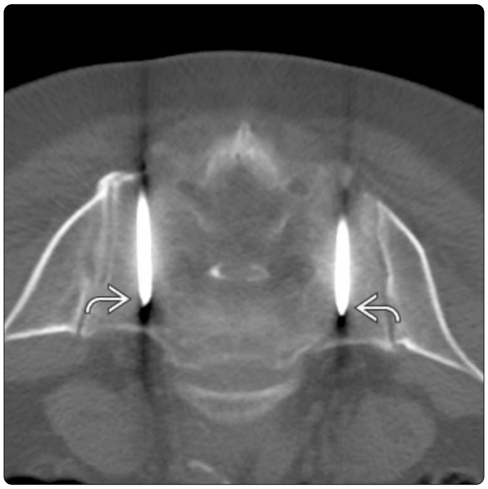


(Left) *MR is the imaging modality of choice for detecting acute sacral insufficiency fractures, although the Honda sign of nuclear scintigraphy has similar sensitivity. Here, coronal MR shows bilateral sacral edema* ➔*, in addition to the signal void of a fracture line* ➔*.* **(Right)** *With the patient prone and the CT gantry tilted craniocaudal (with gantry top away from patient's head), longitudinal sacral imaging can be obtained. Appropriate access sites* ➔ *are then chosen. Note the fracture line* ➔*.*

Sacroplasty (Needle Advancement)

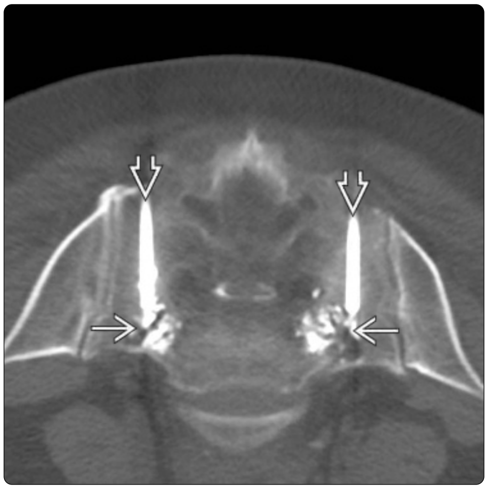


Sacroplasty (Proper Needle Tip Position)

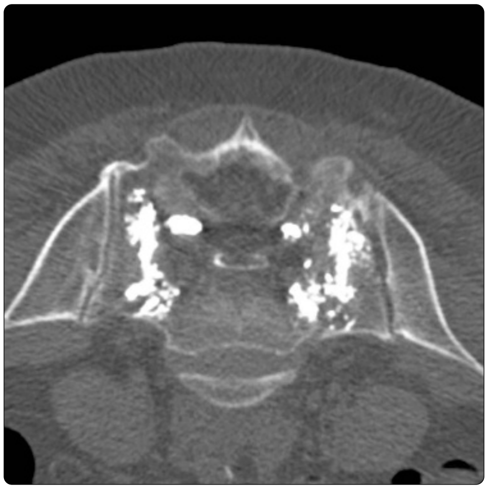


(Left) *Access needles* ➔ *(11-g, in this case) are advanced with intermittent CT guidance, crossing through the S1 and S2 bilateral sacral ala. Beveled needle tips can redirect needles at risk for traversing foraminal or sacral cortex.* **(Right)** *Needle tips are advanced to the S1 sacral ala* ➔*, typically with a somewhat lateral trajectory. Coronal and sagittal CT reconstructions can confirm needle tract and positioning if needed. Cement may be injected utilizing fluoroscopy, CT-fluoroscopy, or frequent CT surveillance.*

Sacroplasty (Cement Injection)

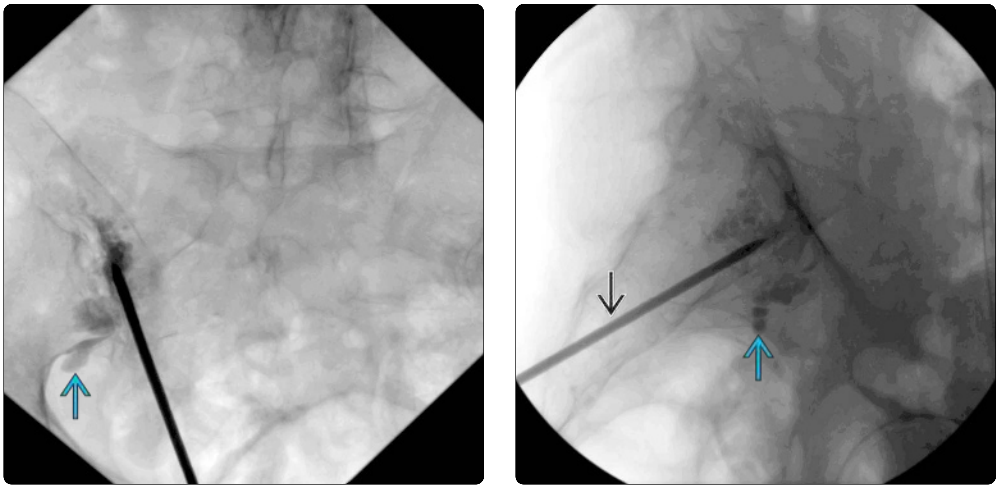


Sacroplasty (Final Imaging)



(Left) *In this case, cement was injected with intermittent CT surveillance. 1.5 cc of cement* ➔ *was injected into each needle* ➔*, needles were withdrawn slightly, and CT imaging was performed. This was followed by repeated 1-cc cement injections, needle withdrawal, and CT imaging.* **(Right)** *4-5 cc of cement is typically injected into each sacral ala. Final imaging shows cement well distributed through the sacral ala without extension into sacral foramen or outside of sacral cortex. Sagittal and coronal imaging can confirm cement position.*

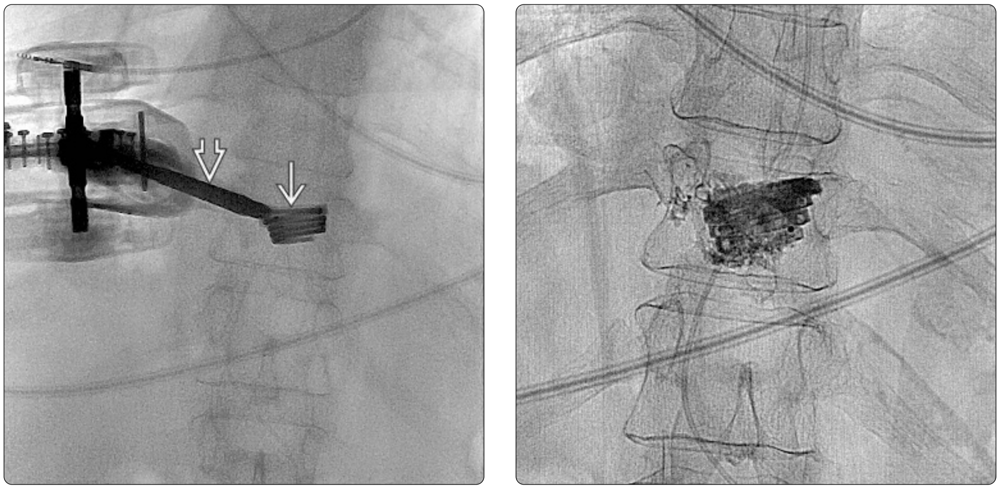
(Left) *In an example of fluoroscopic-guided cement injection, extracortical extravasation of cement* → *is seen.* **(Right)** *The extracortical cement extravasation* → *is seen as well in the sagittal view. The access needle* → *is seen within the sacrum following placement with longitudinal trajectory.*



Sacroplasty: Fluoroscopic-Guided Cement Injection (Coronal)

Sacroplasty: Fluoroscopic-Guided Cement Injection (Sagittal)

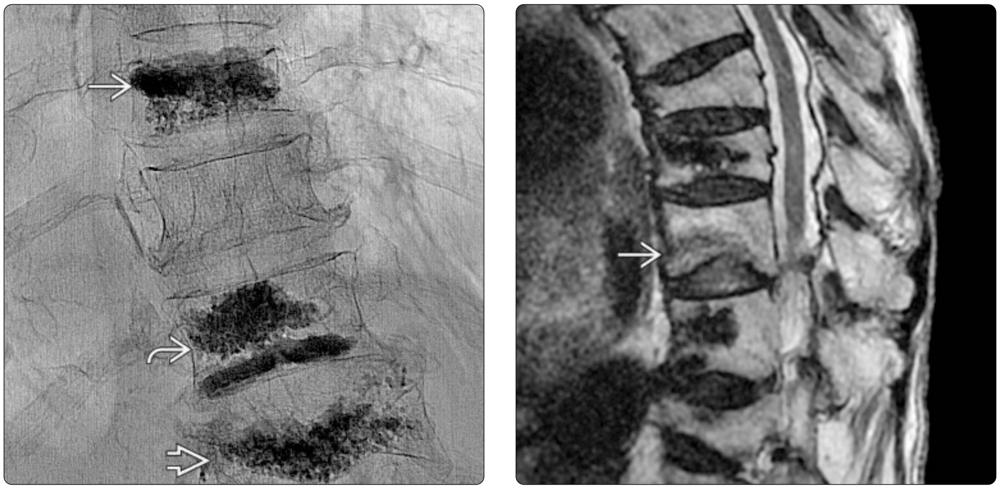
(Left) *Kiva is an alternate vertebral augmentation system whereby a coil-shaped implant* → *is delivered into the vertebral body over a guidewire (subsequently removed), which had been inserted through the transpedicular access needle* →*.* **(Right)** *Cement is then injected through the Kiva implant, extruding through holes in the implant and filling the vertebral body. The implant is designed to limit cement extravasation outside of the vertebral body.*



Kiva Vertebral Compression Fracture Treatment System (Implant Deployment)

Kiva Vertebral Compression Fracture Treatment System (Cement Injection)

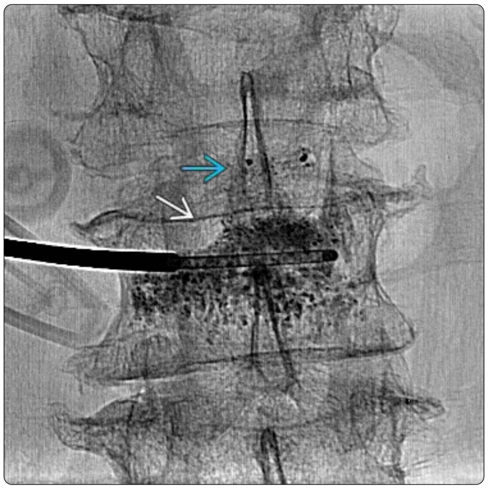
(Left) *A patient called to complain about continuous severe back pain five days after vertebral augmentation of an acute fracture. Fluoroscopic imaging obtained at the time of the procedure shows previous treatment of T10* → *and L1* →*, in addition to the new treatment of T12* →*.* **(Right)** *MR imaging was ordered, revealing a new fracture of T11* →*, which had occurred since the T12 vertebral augmentation. Always consider the possibility of new fracture in patients whose pain fails to improve or returns following treatment.*



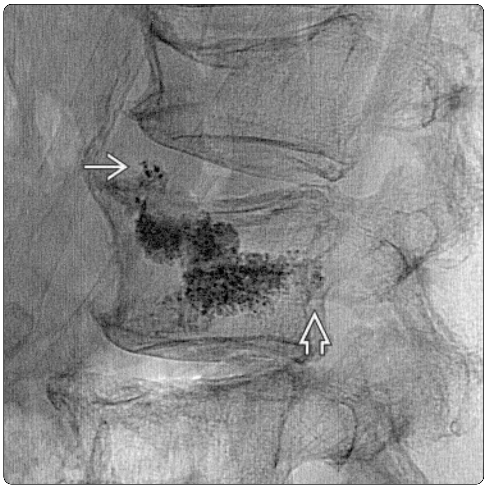
Adjacent Level Fracture: Post Vertebral Augmentation (AP Fluoroscopy)

Adjacent Level Fracture: Post Vertebral Augmentation (Sagittal MR)

Complication: Extracortical Cement Extravasation (AP)

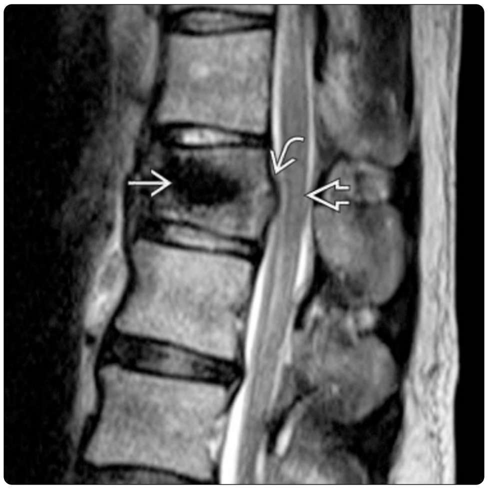


Complication: Extracortical Cement Extravasation (Sagittal)

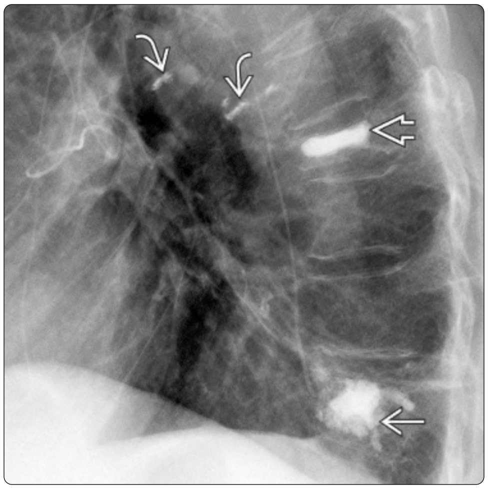


(Left) *Cement ➔ injected via a well-positioned curved curette is seen extending through the superior endplate ➔ into adjacent disc space.* **(Right)** *Sagittal imaging after removal of the curette and access needle shows cement extravasating both through the superior endplate ➔ and posterior of the vertebral body ➔ to the thecal space.*

Complication: Fracture Retropulsion

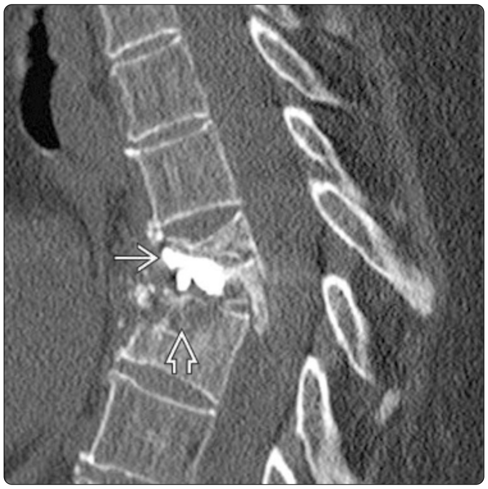


Complication: Intrapulmonary Cement Embolization

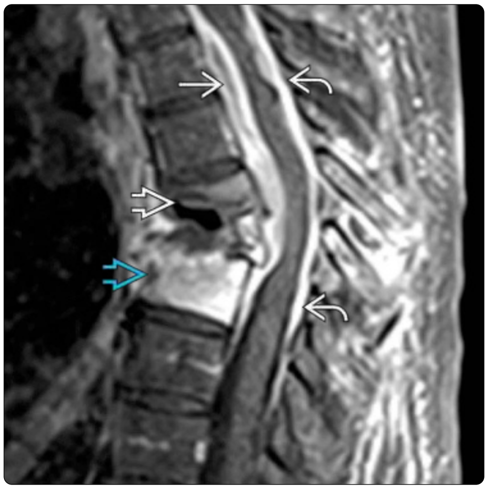


(Left) *Retropulsion of a pathologic vertebral fracture occurred during kyphoplasty ➔. Posterior cortical bowing ➔ impinges on the conus ➔. Kyphoplasty can displace tumor into the spinal canal during balloon inflation, causing spinal cord injury.* **(Right)** *PMMA from a kyphoplasty at T11 ➔ has embolized through the heart into the right upper lobe pulmonary arteries ➔. This can occur when there is extravasation of acrylic into the epidural or paravertebral veins. A prior T8 vertebroplasty is noted ➔.*

Complication: Osteomyelitis With Epidural Spread (CT)



Complication: Osteomyelitis With Epidural Spread (MR)



(Left) *CT reconstruction shows cortical irregularity and destructive changes ➔ from discitis and osteomyelitis involving the vertebral bodies at the level of prior vertebroplasty ➔.* **(Right)** *Sagittal T1 C+ FS MR shows abnormal enhancement at the level of a prior vertebroplasty ➔ and at the adjacent inferior level ➔ from osteomyelitis. There is infectious phlegmon within the epidural space ➔ with a ventral epidural abscess ➔.*

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SECTION 6

Posttransplant Procedures

Transplant Kidney Procedures **672**
Transplant Liver Procedures **684**

Transplant Kidney Procedures

KEY FACTS

TERMINOLOGY

- Transplant renal artery stenosis (TRAS): Luminal narrowing involving or near anastomosis
- Inflow aortoiliac disease (pseudo-TRAS)
- Collections: Hematoma, urinoma, abscess, lymphocele
- Graft intolerance syndrome: Flu-like, due to graft rejection

PREPROCEDURE

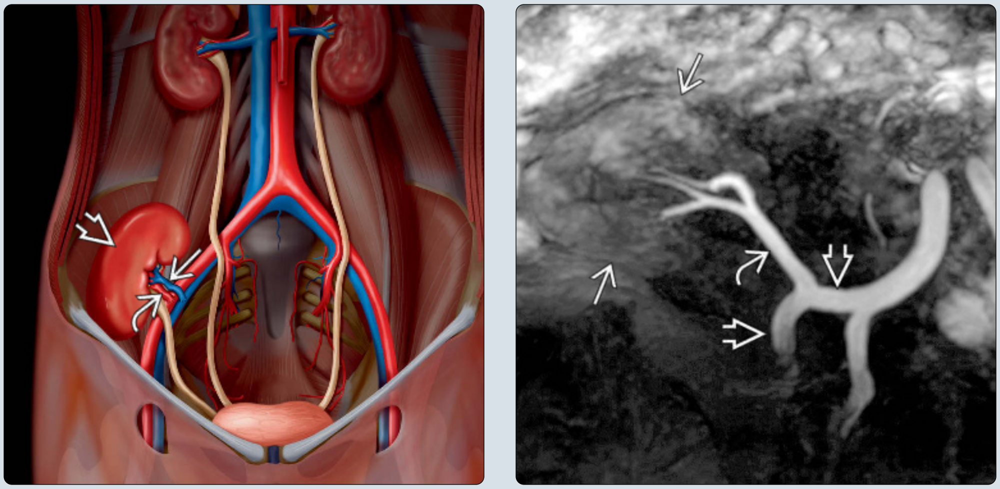
- Review procedure indications; prior imaging
- Review operative history to determine anatomy of arterial/venous/ureteral anastomoses

PROCEDURE

- Endovascular
  - Transplant renal artery stenosis: PTA ± stent
  - Aortoiliac inflow disease: Stent placement
  - AV fistula/pseudoaneurysm: Coil embolization
- Urinary
  - Urinary leak/urinoma: Percutaneous nephrostomy (PCN) or nephroureteral stent (NUS) placement
  - Urinary obstruction: PCN/NUS placement, ureteral balloon dilatation
- Graft/perigraft
  - Perigraft collection: Aspiration/drainage/sclerosis
  - Graft rejection: Percutaneous biopsy
  - Graft intolerance syndrome: Ethanol ablation

OUTCOMES

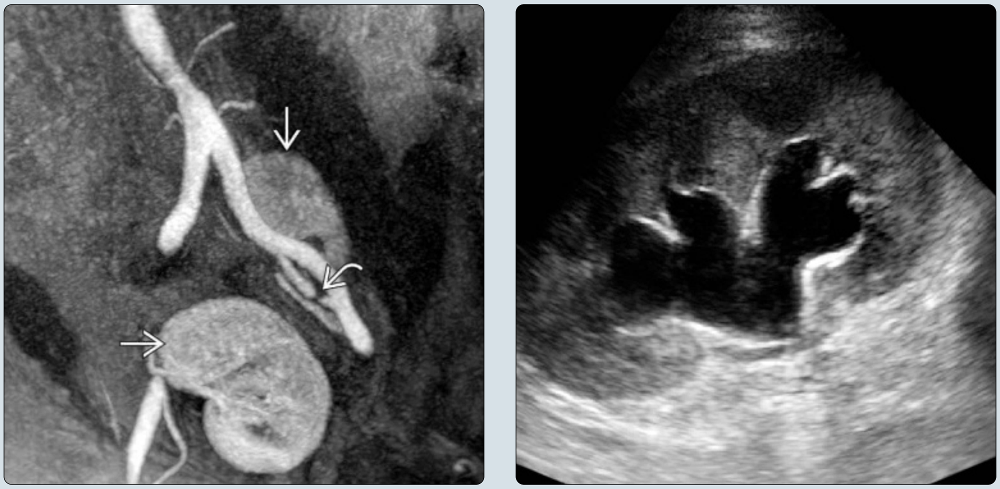
- Clinical success
  - Transplant renal artery stenosis: 82%
  - Arteriovenous fistula/pseudoaneurysm: 57-88%
  - Ureteral stricture
    - Early perianastomotic: 73-100%
    - > 2 cm/typically ischemic: 58-62%
  - Perigraft fluid collections: Abscess: > 90%; urinoma: 36-100%; lymphocele drainage/sclerosis: 68-100%



Typical Renal Transplant Location

Patent Transplant Arterial Anastomosis

(Left) *Graphic shows a renal allograft ⇨ in the right iliac fossa in a retroperitoneal location, with the ureter tunneled into the dome of the bladder. The renal artery ↪ and vein → are anastomosed to the recipient external iliac vessels.* **(Right)** *Coronal noncontrast MRA shows normal arterial anatomy of a right renal allograft →. The donor renal artery ↪ is anastomosed to the recipient's right external iliac artery ⇨, with no evidence of an anastomotic stenosis.*



Transplant Renal Artery Stenosis (Oblique MRA)

Transplant Hydronephrosis

(Left) *Oblique MRA demonstrates the presence of 2 pelvic transplant kidneys → and focal stenosis ↪ of the left transplant kidney's artery. Definitive imaging and potential treatment may be indicated via endovascular means.* **(Right)** *Rising creatinine prompted a diagnostic ultrasound, revealing hydronephrosis of a transplant kidney. Hydronephrosis often results from ureteral stricture related to ischemia or ureteral compression from perigraft collections.*

TERMINOLOGY

Definitions

- **Transplant renal artery stenosis (TRAS)**: Hemodynamically significant narrowing of donor renal artery; often juxtaanastomotic in location; incidence of 3-12%
  - Clinical manifestations
    - Refractory hypertension
    - Renal insufficiency
  - Causes
    - Surgical arterial injury (e.g., anastomotic stenosis)
    - Extrinsic compression by perigraft fibrosis
    - Arterial kinking
- **Proximal pseudostenosis of transplant renal artery (pseudo-TRAS)**
  - Actually due to inflow aortoiliac atherosclerosis
    - Stenosis proximal to transplant artery
    - Incidence up to 2.4%; increases with age
- **Renal graft thrombosis**: Acute thrombotic occlusion of transplant renal artery/vein (incidence up to 6%)
  - **Transplant renal artery thrombosis**
    - Etiologies
      - ☐ Transplant renal artery stenosis
      - ☐ Rejection
    - 80% occur in 1st month
      - ☐ Most common cause of graft loss in 1st week
    - Surgical therapy generally preferred
      - ☐ Surgical treatment faster than endovascular
      - ☐ Because most occur in first 2 weeks, fresh anastomosis poses high risk if thrombolysis used
  - **Transplant renal vein thrombosis**
    - Etiologies
      - ☐ Iliofemoral deep vein thrombosis (DVT)
      - ☐ Compression by perigraft collection
    - Treated with anticoagulation &/or surgery
- **Arteriovenous fistula (AVF)/pseudoaneurysm (PSA)**
  - **AVF**: Abnormal arteriovenous communication
    - Typically occurs after transplant biopsy
    - Involves injury to both artery and vein
    - Clinical features
      - ☐ Gross hematuria, renal insufficiency, hypertension, high-output cardiac failure/bruit
    - May be asymptomatic; may spontaneously resolve
      - ☐ Endovascular therapy if symptomatic/enlarging
  - **PSA**: Contained leak from injured artery, with connecting tract to sac-like blood collection contained in perivascular space
    - Incidence: 1-18% after biopsy
    - Clinical feature: Hematuria
    - AVF and PSA may coexist
    - Endovascular therapy if symptomatic/enlarging
      - ☐ Transcatheter coil embolization
- **Urinary obstruction/leak**
  - Incidence: 3-10%
    - Often within 6 months of transplantation
  - Etiologies
    - Often due to distal ureteral ischemia (ureteral vascular supply arises from renal hilum)
    - Obstructing calculus
    - Ureteral extrinsic compression or kinking
  - Can diagnose leak by creatinine level in urinoma
    - High infection risk if immunocompromised
    - May require both percutaneous nephrostomy (PCN) and urinoma drain for treatment
- **Perigraft fluid collection**
  - Occurs in up to 50% of patients
    - 15-20% clinically significant due to
      - ☐ Pain
      - ☐ Transplant dysfunction from vascular/ureteral compression
  - Etiologies in early postoperative period
    - Hematoma (early postoperative period)
    - Abscess (1st several postoperative weeks)
    - Urinoma (higher creatinine vs. serum creatinine)
  - Etiology after 1st month
    - Lymphocele (protein, urea nitrogen, creatinine similar to serum levels)
- **Graft intolerance syndrome**
  - Syndrome due to graft rejection
    - Fever, flu-like syndrome, local pain
  - Consider percutaneous/transcatheter ablation of renal transplant with ethanol
    - Prior to nephrectomy to reduce bleeding
- **Cadaveric renal transplant**
  - Harvested renal artery with portion of aorta; anastomosed end-to-side to recipient external iliac artery (EIA)
  - 5-year 82% survival rate
- **Living donor renal transplant**
  - Harvested renal artery without aorta; anastomosed end-to-side to recipient EIA, or end-to-end to recipient internal iliac artery
  - 5-year 90% survival rate

PREPROCEDURE

Indications

- Endovascular
  - Angioplasty/stenting
    - Transplant renal artery stenosis
    - Aortoiliac inflow stenosis
      - ☐ Compromised transplant renal artery inflow
    - Arterial dissection
  - Thrombolysis
    - Renal artery thrombosis
      - ☐ Low clot burden
      - ☐ Poor surgical candidate
  - Embolization
    - AFV/PSA
- Urinary collecting system
  - Nephrostomy/ureteral stent placement
    - Ureteral stenosis/obstruction
    - Urine leak/urinoma
  - Ureteral balloon dilation
    - Ureteral stenosis
- Graft/perigraft
  - Percutaneous aspiration/drainage
    - Perigraft fluid collection
  - Percutaneous transplant renal biopsy

    - Rejection suspected

Contraindications

- Lack of safe access for intervention
- Uncorrectable coagulopathy
- Arterial kinking
  - Better suited to surgical management
- Renal artery thrombosis with high clot burden or occurring within first 2 weeks after surgery
  - Surgical exploration preferred
  - Risk to anastomosis in first 2 weeks

Preprocedure Imaging

- US
  - Arterial stenosis
    - Elevated peak systolic velocity > 200-250 cm/s
    - > 2:1 peak systolic velocity post:prestenosis
    - Parvus et tardus waveform, low pulsatility index
    - Acceleration time > 100 ms
  - AVF
    - Abnormal artery/vein communication
    - High velocity, low diastolic flow
  - PSA
    - Pulsatile color Doppler flow within PSA sac
    - Swirling flow/turbulence/yin-yang sign in sac
    - Tract/neck connects PSA and feeding vessel
    - Biphasic arterial Doppler signal in tract/neck
  - Renal artery thrombosis
    - Lack of main or intrarenal artery flow
  - Renal vein thrombosis
    - Lack of renal venous flow
    - Enlarged kidney (allograft edema)
  - Ureteral obstruction
    - If concern for due to hydronephrosis, empty bladder and reimage
  - Perigraft fluid collection
    - Hematoma
      - Echogenic components if acute
      - Hypoechoic, anechoic layering while resolving
    - Abscess: Hypoechoic/mixed echogenicity ± septations
    - Urinoma: Anechoic collection
    - Lymphocele: Rounded, anechoic collection ± septa
- MR/CT
  - May demonstrate location of stenosis
    - Involving or adjacent to arterial anastomosis
    - Aortoiliac inflow disease
    - Tortuous/kinked artery may be well demonstrated
  - MRA
    - May be performed ± gadolinium
      - Glomerular filtration rate (eGFR) important
      - Risk of nephrogenic systemic fibrosis (NSF) if severe renal dysfunction and gadolinium given
    - Susceptible to artifact from metallic stents
  - CT
    - Good for evaluating hydronephrosis
    - Characterization of perigraft fluid collection
      - Abscess may contain air
      - Hematoma may contain hyperdense areas
  - CTA
    - Requires iodinated contrast
    - Risk of contrast-induced nephropathy
  - DSA
    - Gold standard for diagnosis/endovascular treatment of transplant renal artery stenosis
      - Invasive and with ionizing radiation
    - Possible to reduce risk of contrast-induced nephropathy
      - Can use CO_2 or dilute iodinated contrast
      - Selective vessel catheterization
    - High-resolution imaging & guidance for intervention
- Renal nuclear scintigram
  - Confirm urinary obstruction/leak
- Retrograde pyelogram
  - If ureteroureterostomy/ureteropyelostomy present
  - Evaluate urinary obstruction/leak

Getting Started

- Things to check
  - Transplant operative history
    - Cadaveric or living donor
    - Arterial anastomosis
      - End-to-side of common/EIA
      - End-to-end of internal iliac artery (living donor)
    - Venous anastomosis
      - End-to-side of common/external iliac vein
    - Ureteral anastomosis
      - Ureteroneocystostomy (most common)
      - Ureteroureterostomy
      - Ureteropyelostomy
    - Children < 20 kg
      - Transplant more cephalad in location
      - End-to-side anastomoses to distal aorta and IVC
  - Pertinent clinical history and physical examination
    - Procedure indications; prior imaging
    - Current medications
      - Any anticoagulant or antiplatelet agents
    - Allergies
  - Laboratory parameters
    - Complete blood count (CBC)
      - Platelet > 50,000/μL
    - Coagulation profile
      - International normalized ratio (INR) ≤ 1.5
      - Normal prothrombin time (PT), partial thromboplastin time
    - eGFR
      - Is there renal dysfunction?
      - Reduced eGFR may impact procedure
    - Cyclosporine level
      - Is graft dysfunction due to toxicity?
- Medications
  - Anesthesia
    - 1% lidocaine local anesthetic
    - Adequate procedural sedation
      - Fentanyl, midazolam typically used
    - Anesthesiology assistance if necessary
  - Prophylactic antibiotics
    - PCN
    - Perigraft collection aspiration/drainage
      - e.g., ampicillin (1 g), gentamicin (80 mg)
  - Heparin

        - Administered prior to crossing arterial stenosis
    - Vasodilator (e.g., nitroglycerin)
        - Typical bolus dose of 100 µg nitroglycerin
        - Prevents/treats catheter-induced vasospasm
    - Thrombolytic agent
        - e.g., tissue plasminogen activator (tPA)
- Equipment list
    - General
        - US equipment
            - 3- to 5-MHz transducer
            - Sterile ultrasound probe cover/gel
        - Fluoroscopy equipment (C-arm)
        - Computed tomography equipment
            - Radiopaque skin grid
    - Arterial revascularization/exclusion
        - Micropuncture access set
        - Catheters/sheaths
            - 5- to 6-Fr arterial access sheath
            - Flush catheter (e.g., pigtail, OmniFlush)
            - Selective catheter (e.g., Cobra-2)
            - Guiding catheter/sheath; permits contrast injection around stent during placement
            - Microcatheter (primarily for embolization)
        - Guidewires
            - Initial 0.035" guidewire
            - Hydrophilic guidewire
            - Floppy tip guidewire for crossing stenosis
            - 0.014-0.018" microwire
            - Stiff guidewire (e.g., Rosen, McNamara)
        - Angioplasty (PTA) balloon
            - Match balloon and lesion lengths
            - Over-the-wire vs. rapid exchange system
        - Intravascular stents
            - Prefer high radial force balloon-mounted stent
            - Introduced coaxially via guiding catheter; rapid exchange system
        - Embolic agents
            - Embolization coils
        - Isosmolar iodinated contrast
            - Use small volumes of dilute contrast
            - Consider CO_2 contrast use if renal dysfunction
    - Thrombolysis
        - Infusion catheter
    - Biopsy
        - 16-g spring-loaded core biopsy gun
        - Coaxial biopsy system
            - e.g., 17-g introducer/18-g core biopsy gun
    - PCN/ureteral stent
        - Percutaneous access needles
            - 21- to 22-g Chiba needle
            - 18-g longdwell needle (e.g., Ring) if 2-stick technique used
        - Guidewires
            - 0.018" mandril or nitinol guidewire
            - 0.035" 3-J guidewire
        - Catheters/sheaths
            - 5- to 6-Fr coaxial dilator-sheath assembly
            - 5-Fr directional catheter (e.g., Kumpe)
            - 8-Fr locking pigtail nephrostomy catheter
        - Ureteral stent
            - 9- to 10-Fr peel-away sheath
            - 8-Fr double J ureteral stent
    - Ureteral balloon dilatation
        - 0.035" stiff guidewire (e.g., Amplatz)
        - Angioplasty balloon (5-8 mm diameter)
    - Aspiration/drainage
        - Direct trocar technique
            - 8- to 14-Fr trocar-mounted locking pigtail catheter
        - Tandem-trocar technique
            - 20-g Chiba guiding needle
            - 8- to 14-Fr locking pigtail catheter
        - Seldinger technique
            - Access needle (e.g., 18-g longdwell needle)
            - 0.035" 3-J guidewire
            - 8- to 14-Fr dilators as appropriate
            - 8- to 14-Fr locking pigtail catheter
        - Aspiration without drainage catheter placement
            - 18- to 22-g spinal needle (diagnostic aspiration)
            - 7-Fr curved-tip catheter (diagnostic/therapeutic aspiration)

PROCEDURE

Patient Position/Location

- Best procedure approach
    - **Endovascular intervention**
        - Common/EIA anastomosis
            - Ipsilateral or contralateral femoral approach
        - Internal iliac artery anastomosis
            - Contralateral femoral approach
    - **Allograft biopsy**
        - Supine
        - Direct biopsy trajectory away from hilum toward upper or lower pole
            - Reduces risk for PSA/AVF/hematuria
    - **PCN/ureteral intervention**
        - Supine
        - Lateral approach to prevent transperitoneal trajectory
    - **Aspiration/drainage**: Supine

Procedure Steps

- **Arterial revascularization for stenosis**
    - Obtain arterial access; place access sheath
    - Perform nonselective CO_2 aortoiliac DSA
        - Position flush catheter above aortic bifurcation
        - Assess for inflow atherosclerotic stenosis
    - If TRAS shown by other imaging (e.g., US), proceed directly to selective DSA of inflow/target artery
    - Perform common/external/internal iliac DSA
        - Target artery depends on anastomosis location
        - Acquire images in multiple C-arm projections
        - Stenosis typically near anastomosis
    - Place guiding catheter/sheath in target artery
    - Advance 4- to 5-Fr coaxial catheter proximal to stenosis
        - Inject contrast; obtain DSA images
            - Use either CO_2 or small volume of dilute iodinated contrast medium
    - Evaluate length and severity of stenosis
        - Criteria

      - Luminal narrowing > 50%
      - Pressure gradient > 10% of peak systolic pressure
  - Administer IV heparin
    - 70 U/kg bolus or empiric 2,500-5,000 units
      - Goal: Activated clotting time (ACT) 250-300 s
  - Consider intraarterial nitroglycerin (100-200 μg)
    - Administer on "as needed" basis for vasospasm
  - Traverse stenosis
    - Advance floppy-tip guidewire through stenosis
      - Stop advancing if resistance encountered
      - Assess for guidewire passed subintimally
      - Avoid dissection
    - Advance selective catheter over guidewire
      - Inject contrast to confirm beyond lesion
    - Exchange for stiff, curved-tip guidewire (e.g., Rosen/McNamara)
  - Proceed to angioplasty &/or stenting
  - **PTA**
    - Match balloon size to normal artery diameter
      - Consider using coaxial rapid-exchange system; smaller caliber system, less traumatic
    - Maintain guidewire across lesion
    - Center angioplasty balloon with lesion
    - Use insufflator for balloon inflation
      - Inflate with 50/50 contrast/saline mix
    - Balloon "waist" typically created by stenosis
      - With continued inflation, "waist" should release
    - Deflate and remove angioplasty balloon catheter
      - Maintain guidewire across lesion
      - Recrossing lesion with guidewire has dissection risk
    - Inject contrast via guiding catheter/sheath
      - Document angioplasty result
      - Technical success = residual stenosis < 20-30%
      - Repeat angioplasty if necessary
  - **Intravascular stenting**
    - Indications
      - Aortoiliac inflow disease
      - > 30% residual stenosis after angioplasty of TRAS
      - Flow-limiting dissection
    - Select appropriate balloon-mounted stent
      - Consider using guiding catheter and coaxial rapid-exchange system
    - Position stent
      - Stent should encompass entire stenosis
      - Inject guiding catheter/sheath during deployment; confirm position
    - Retract guiding catheter/sheath
    - Fully inflate balloon to deploy stent
    - If self-expanding stent used
      - Retract outer constraining sheath of delivery system while maintaining stent position
      - Perform postdeployment angioplasty
  - Perform completion DSA arteriogram
    - Determine technical success/document results
    - Exclude complications
  - Remove catheters/sheath; obtain hemostasis
- **Thrombolysis of renal artery thrombosis**
  - Selectively catheterize thrombosed target artery
    - Advance guidewire through thrombosed lumen
  - Administer IV heparin
  - Exchange over guidewire for infusion catheter
  - Place tip of infusion catheter beyond anastomosis
  - Begin continuous infusion with thrombolytic (e.g., tPA)
  - Admit to ICU for appropriate monitoring
  - Obtain DSA after thrombolysis; assess for TRAS
    - Treat underlying stenosis with angioplasty/stent
    - Arterial kinking may require surgical correction
- **AVF/PSA**
  - **General**
    - Obtain DSA of transplant kidney vasculature
    - Introduce microcatheter into target artery
    - Selectively catheterize branch leading to PSA/AVF
    - Perform coil embolization of nidus
  - **PSA**
    - Position catheter tip within PSA sac
    - Tightly deposit coils in sac to thrombose
    - May sometimes need to place coils in arterial lumen proximal/distal to PSA
      - Particularly if wide-mouthed PSA
    - Also consider stent-assisted coil embolization
  - **AVF**
    - High arterial flow risks nontarget embolization
      - Consider using detachable coils; more precise
    - May require simultaneous arterial/venous catheterization
      - Position balloon in venous side
      - Inflate balloon to reduce flow
      - Deposit coils along fistula from arterial side
  - Perform completion angiogram
    - May be unable to completely obliterate PSA/AVF with coil embolization
      - Difficult with large/high-flow lesions
- **Ethanol ablation of rejected transplant**
  - Selectively catheterize transplant renal artery
  - Perform renal DSA; exclude any other abnormality
  - Exchange diagnostic for balloon occlusion catheter
  - Inflate balloon to occlude proximal renal artery
  - Inject contrast to visualize renal branch vessels
    - Note contrast volume used to visualize branches
  - Slowly inject similar volume of absolute ethanol
  - Repeat contrast injection; confirm ablated vessels
  - Concurrent coil embolization of renal artery optional
- **Biopsy**
  - Coaxial vs. single-needle technique
  - Use real-time US guidance; advance needle to target
  - Orient trajectory toward upper or lower pole
    - Needle should be oriented away from renal hilum
    - Tough scar tissue may overly kidney
  - Enter cortex; maintain trajectory parallel to cortex
  - Obtain biopsy
  - Remove needle and prepare specimen
  - May repeat if additional samples desired
  - Perform postbiopsy ultrasound
    - Assess for perirenal hematoma
  - Use CT guidance if poor US visualization (rare)
- **PCN for urinary obstruction/leak**
  - Visualize transplant kidney with US
  - Select lateral calyx

  - Use 1- or 2-stick technique
  - **Nephroureteral catheter placement**
    - Avoid in septic patient; place PCN, delay nephroureteral catheter placement until clinically improved
  - **Antegrade ureteral stent placement**
    - Same steps as nephroureteral catheter placement, advance Amplatz wire to coil in bladder
      - May use combination of hydrophilic guidewire and 5-Fr directional catheter to cross stenosis
    - Select appropriate-length 8-Fr double pigtail stent (pediatric lengths available)
  - **Ureteral balloon dilation**
    - Indicated in high-grade anastomotic stricture
    - Advance Amplatz wire across stenosis
    - Select balloon: Match diameter of normal ureter
    - Position balloon across stenosis
    - Insufflate 10-12 atm for 30-120 s
      - May see "waist" at stenosis
      - Continued inflation should eliminate waist
    - Repeat dilatation until waist disappears
      - May upsize balloon if waist does not disappear
    - Inject contrast; assess for residual stenosis
    - Place nephroureteral catheter or antegrade stent/safety nephrostomy catheter
- **Aspiration/drainage**
  - Can aspirate/drain most perigraft collections using US guidance
  - **Aspiration**
    - Localize fluid collection with US
    - Use Doppler to avoid any intervening vessels
    - Prep skin, administer 1% lidocaine anesthetic
    - Nick skin with #11 scalpel blade
    - Advance spinal needle or 5- to 7-Fr trocar/catheter into collection using real-time US
      - Use needle if diagnostic aspiration only
      - Use catheter if therapeutic/complete aspiration
      - Once catheter tip in collection, unscrew hub and advance catheter into collection
    - Connect to extension tubing and 3-way stopcock
    - Perform syringe aspiration
    - Submit specimens for
      - Gram stain, culture and sensitivity; creatinine assay; cell count
    - US to assess residual collection
    - Loculated component may require separate catheter placement
  - **Drainage**
    - Select appropriate catheter: 8- to 14-Fr available
      - 8- to 10-Fr typically used
      - Viscous collections may require 12- to 14-Fr catheters
    - Direct trocar technique
      - Load locking pigtail catheter over trocar
      - Advance catheter assembly into collection using real-time US guidance
      - Unscrew trocar from catheter once tip of catheter assembly is in collection
      - Stabilize trocar so it no longer advances; advance catheter further into collection
      - Remove trocar; form/lock pigtail
      - Connect to extension tubing, 3-way stopcock, and drainage bag
      - Demonstrate pigtail loop in collection with US
      - Aspirate fluid
      - Confirm interval drainage by US
    - Seldinger technique
      - US and fluoroscopic guidance are complementary
      - Advance access needle (e.g., 18-g) into collection using US guidance
      - Aspirate small amount of fluid
      - May confirm position in collection by contrast injection under fluoroscopic monitoring
      - Inspect fluid for color, purulence, viscosity
      - Select catheter size based on fluid viscosity
      - Advance 0.035" stiff guidewire into collection
      - Remove needle/Ring sheath
      - Nick skin, dilate tract as appropriate
      - Load catheter on stiffening cannula
      - Advance assembly over wire into collection
      - Once assembly tip in collection, unscrew hub
      - While stabilizing cannula so it does not advance, advance catheter over guidewire further into collection
      - Remove stiffener and wire
      - Form/lock pigtail
      - Connect drainage assembly as previously detailed with direct trocar technique
    - CT-guidance rarely required
  - Drainage and sclerotherapy of lymphoceles
    - Place drainage catheter into collection
      - Aspirate contents of collection
    - Inject contrast via drainage catheter
      - Exclude communication with collecting system
      - Note volume of collection
    - Various sclerosants available (e.g., ethanol, fibrin sealant, sodium tetradecyl sulfate, bleomycin)
    - Inject volume of sclerosant < volume of cavity
    - May clamp catheter; sclerosant indwell up to 15 min
    - Unclamp catheter and aspirate contents
    - May require several treatments

Alternative Procedures/Therapies

- Surgical
  - Arterial kink: Surgical revascularization
  - Lymphocele: Surgical marsupialization

POST PROCEDURE

Things to Do

- Arterial revascularization
  - Intravenous hydration; monitor blood pressure
  - Antiplatelet therapy
    - Clopidogrel 75 mg daily for 3 months
    - Aspirin 81 or 325 mg over lifetime
- PCN/nephroureteral catheter
  - Some recommend flushing, not always required if no hematuria/clogging of catheter
  - Regular catheter exchanges every 4-12 weeks
    - More frequent if high urinary sediment/clogging
    - Prophylactic antibiotics prior to every change

      - Tailor to previous culture results
    - Minimize contrast injection volume/guidewire manipulations
      - Reduces risk of sepsis
  - Ureteral stent post placement
    - Consider externally clamping PCN next day
    - Clamp trial may extend 1-7 days
      - Unclamp PCN if pain or fever develops
    - Antegrade nephroureterogram via PCN at end of trial
      - If patent stent, may remove PCN
    - Regular retrograde stent changes by urology
  - Ureteroplasty
    - Plan to repeat at time of nephroureteral catheter exchange
    - Discuss with transplant service appropriate # of ureteroplasty procedures to attempt before stenosis/occlusion considered nonresponsive
- Drainage
  - Record drain output q shift
  - Flush catheter with 10 mL normal saline q 8-12 h
  - More frequent flushes if fluid tenacious
  - Always flush after aspiration
  - Catheter removal criteria
    - Resolution of fever/leukocytosis/night sweats
    - Hemodynamically stable
    - Drainage catheter output < 10-20 mL/day
    - No fistula or large cavity on catheter injection

Postprocedure Imaging

- Stenosis/AVF/PSA
  - Follow-up duplex sonography
- PCN/ureteral stent
  - Antegrade nephrostogram when clinically improved
    - Evaluate via sheath while catheter removed over wire
    - May not obtain complete nephrostogram during PCN if septic
    - If ureteral stenosis found, consider balloon dilatation and nephroureteral catheter/stent placement

OUTCOMES

Problems

- Restenosis
  - Repeat angioplasty, stent placement
  - In-stent stenosis (13-25% incidence)
    - Consider angioplasty of stent/new stent
    - Cutting balloon angioplasty
- Failure to improve hypertension or eGFR
  - Rejection, technical failure, or irreversible renal damage

Complications

- Most feared complication(s)
  - Loss of renal allograft
  - 0-10% flow-limiting renal artery injury (e.g., thrombosis, dissection)
    - Maintain guidewire position across dissection
    - Place intravascular stent
  - Renal artery perforation/rupture
    - Maintain guidewire position across lesion
    - Reverse anticoagulation
    - Inflate angioplasty balloon across perforation for arterial tamponade
    - Place covered stent bridging injury
    - Use coil embolization for distal rupture
- Immediate/periprocedural complication(s)
  - Hemorrhage
    - May see transient hematuria after biopsy or PCN
  - Infection/sepsis
  - AVF/PSA
    - May occur after transplant biopsy
    - May occur after PCN
- Delayed complication(s)
  - Arterial in-stent restenosis
- Other complications
  - Vascular access complications
  - Bladder irritation/pain from nephroureteral catheter or ureteral stent
    - May consider cutting nephroureteral catheter so that distal tip terminates in ureter
    - May require conversion to PCN
  - Ureteral stent occlusion: Exchange stent over wire
  - Postembolization syndrome

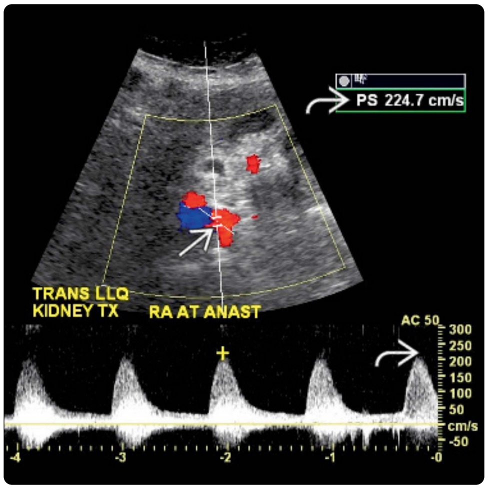
Expected Outcomes

- Transplant renal artery stenosis
  - Technical success rate reported as high as 94%
  - 95% graft survival post-PTA at 1 year; 82% at 2 years
  - PTS success > end-to-side anastomosis (91%) vs. end-to-end (75%)
  - 82% clinical success (defined as)
    - > 15% reduction in serum creatinine
    - > 15% reduction in diastolic blood pressure with no change in antihypertensive medications
    - > 10% reduction in diastolic blood pressure with reduction in antihypertensive medications
- AVF/PSA
  - Technical success: 71-100%
  - Clinical success: 57-88%
    - Procedure may be repeated if necessary
  - Minor infarcts (involving < 30% kidney) may occur
    - Usually clinically insignificant
    - Recommend using coils as higher risk of major infarct with particles; risk allograft loss
- Urinary obstruction
  - Clinical success following ureteroplasty/stent placement
    - High-grade perianastomotic: 73-100%
    - Strictures > 2 cm or ischemic: 58-62%
- Aspiration/drainage
  - Abscess: > 90%
  - Lymphocele
    - 80-90% recurrence with aspiration alone
    - 68-100% clinical success when drainage combined with sclerotherapy
- Urine leak: Success following urinary diversion: 36-100%

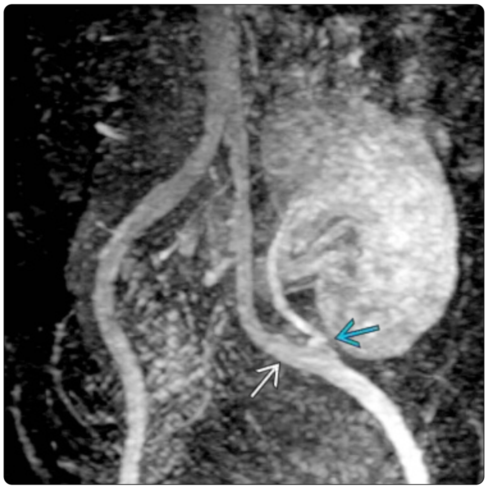
SELECTED REFERENCES

1. Copelan A et al: Iatrogenic-related transplant injuries: the role of the interventional radiologist. Semin Intervent Radiol. 32(2):133-55, 2015

Transplant Renal Artery Stenosis

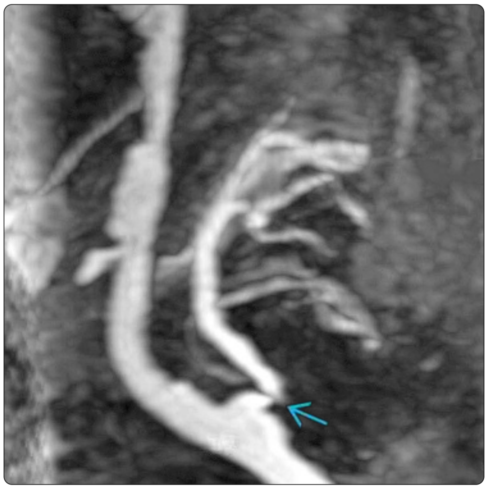


Transplant Renal Artery Stenosis (MRA Evaluation)

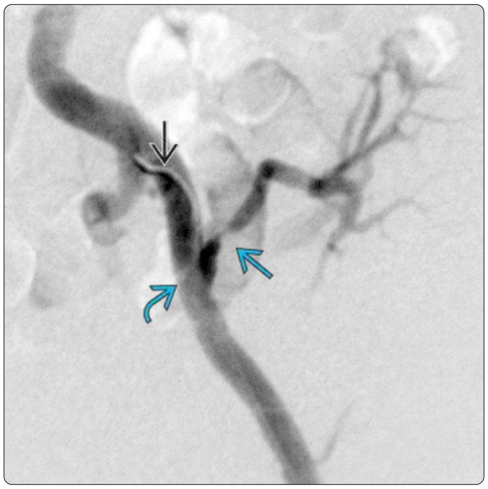


(Left) *Color Doppler evaluation of the donor renal artery to native external iliac artery anastomosis* → *shows marked elevation of peak systolic velocities* →. *This suggests high-grade renal artery anastomotic stenosis, commonly caused by anastomotic stricture or vascular clamp injury.* **(Right)** *Oblique maximum intensity projection (MIP) from an MRA in the same patient suggests an acute angulation* → *of the donor renal artery near the anastomosis to the native left external iliac artery* →.

Transplant Renal Artery Stenosis (MRA Postgadolinium Evaluation)

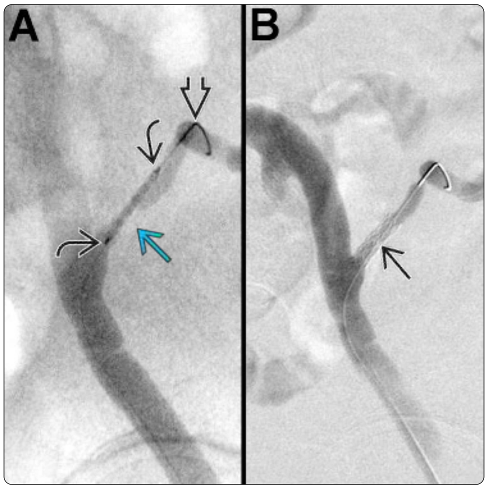


Transplant Renal Artery Stenosis (Diagnostic DSA Evaluation)

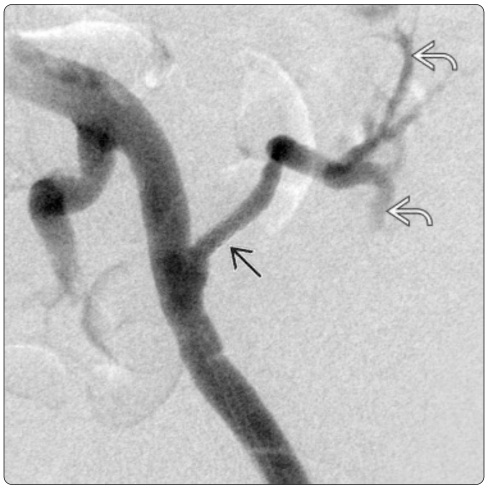


(Left) *Additional postgadolinium MRA confirms stenosis of the proximal transplant renal artery in the area of acute angulation* → *near the anastomosis.* **(Right)** *A catheter was introduced from an ipsilateral left common femoral approach, and the catheter tip* → *placed in the external iliac artery proximal to the end-to-side renal artery anastomosis* →. *The DSA confirms focal, high-grade renal artery stenosis* →.

Transplant Renal Artery Stenosis (Intravascular Stent Placement)

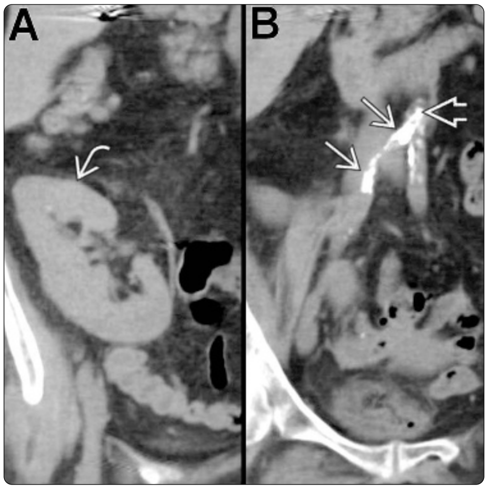


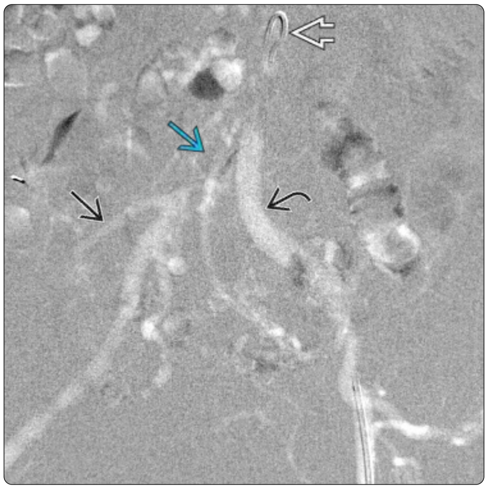
Transplant Renal Artery Stenosis (Post Stent Deployment)



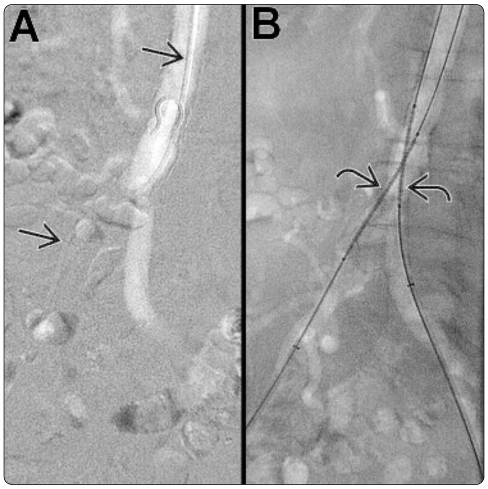
(Left) *Fluoroscopic spot radiographs during intravascular stent placement show (A) a balloon-mounted stent* → *advanced over a guidewire* → *bridging the stenosis* →. *(B) After expanding the stent* →, *the stenosis has been eliminated.* **(Right)** *After removal of the stent delivery system and guidewire, a repeat DSA was obtained. The anastomotic stent* → *is in satisfactory position and there is no residual stenosis. The intrarenal arterial branches* → *fill normally.*

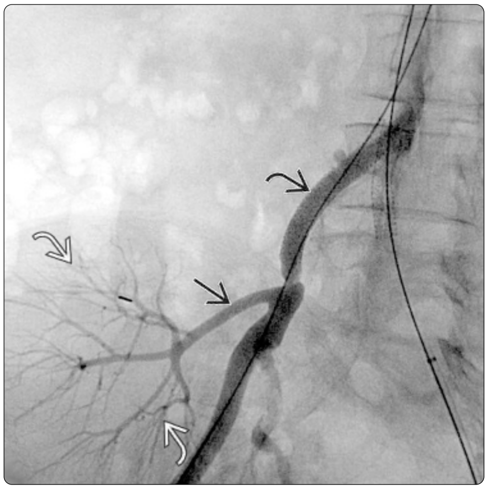
(Left) *Coronal NECT in a failing renal transplant shows (A) the transplant kidney ↪ in the right iliac fossa, anastomosed end-to-side to the common iliac artery. (B) Extensive calcified plaque in the right common iliac artery → extends into the distal abdominal aorta ⇨.* **(Right)** *DSA pelvic arteriography was performed with CO₂ contrast via a Omniflush catheter ⇨ advanced through the less-diseased left iliac artery ↪. Contrast is absent within the occluded right common iliac artery →. The transplant renal artery → is patent.*


Inflow Aortoiliac Disease (Pseudo-TRAS)

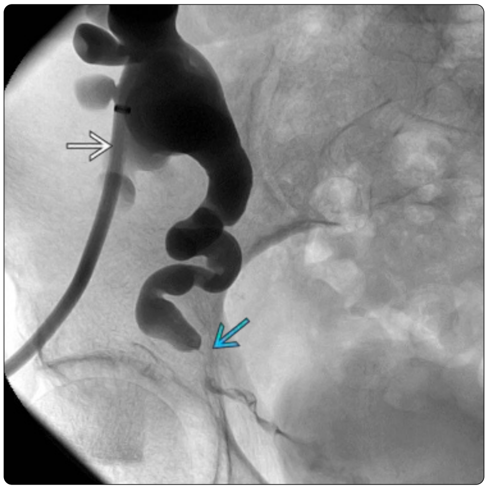

Inflow Aortoiliac Disease (Pelvic Arteriogram DSA With CO₂ Contrast)

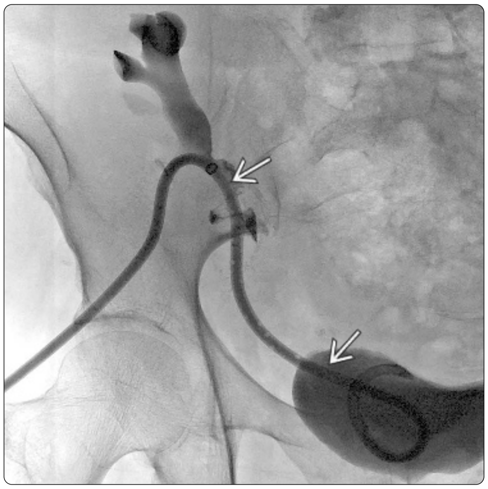
(Left) *(A) The right femoral artery was accessed, and a guidewire and catheter → were used to traverse the occluded right common iliac artery. (B) In order to restore right iliac flow, while preventing plaque dislodgement into the left iliac artery, balloon-mounted "kissing" stents ↪ were deployed simultaneously in the common iliac arteries.* **(Right)** *Right iliac artery ↪ inflow is restored following placement of "kissing" stents. The transplant renal artery → and intrarenal branches ↪ now fill normally.*


Inflow Aortoiliac Disease (Stenting of Iliac Artery Occlusion)

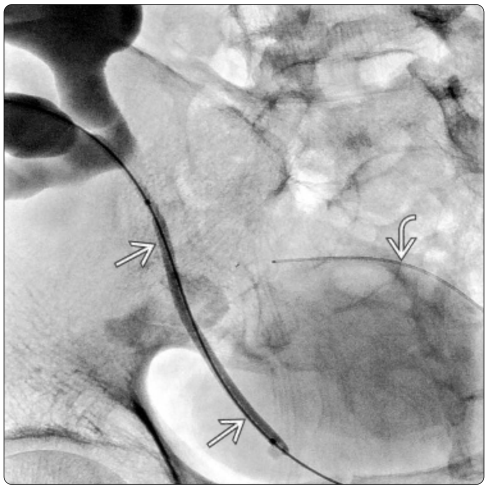

Inflow Aortoiliac Disease (Postintervention DSA Imaging)

(Left) *A percutaneous nephrostomy (PCN) → was placed in a hydronephrotic transplant kidney and left to drain overnight. An antegrade nephrostogram performed the next day revealed high-grade stenosis of the mid ureter →.* **(Right)** *The PCN was converted to a NUS (biliary-type with multiple side-holes) →, which was capped externally. Maintaining percutaneous access allows repeated ureteroplasty at timed intervals, plus intermittent stent enlargement which can "stretch" the stenosis and restore patency in some cases.*

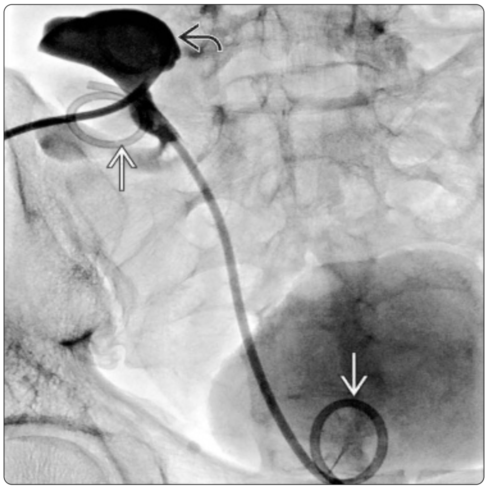

Ureteral Stricture (Antegrade Nephroureterogram)


Ureteral Stricture (Post Placement of Internal/External Nephroureteral Stent)

Ureteroplasty and Stent Internalization (Balloon Dilation)

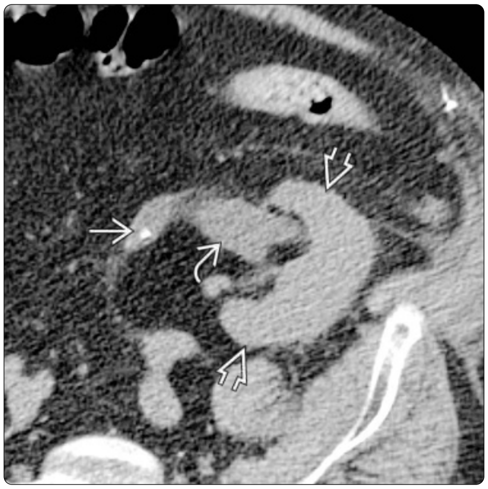


Ureteroplasty and Stent Internalization (Post Placement of Internal Double-J Ureteral Stent)

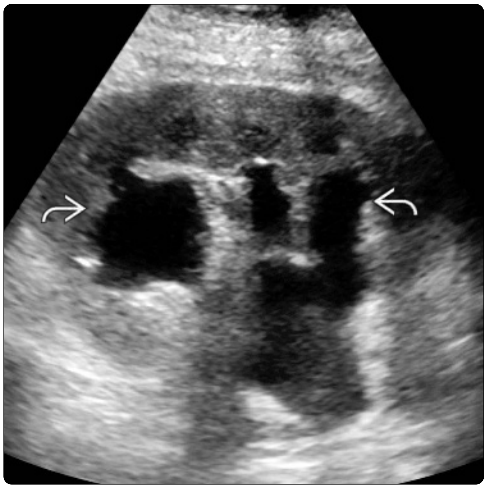


(Left) *Long ureteral stricture is treated with ureteroplasty. A balloon ➡ has been introduced over a guidewire ↪ and has been inflated to dilate the stricture. Ureteral ischemia is the main cause of these strictures.* **(Right)** *Following balloon dilatation, a double pigtail ureteral stent ➡ was introduced and placed across the stricture. Urology will manage the stent at this point. A safety nephrostomy catheter ⤻ was temporarily left indwelling and may be removed over a wire in a day or two.*

Renal Transplant Urinary Obstruction (Initial NECT Evaluation)

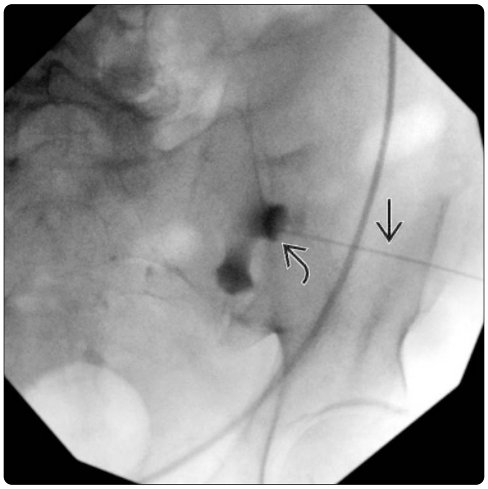


Renal Transplant Urinary Obstruction (Initial US Evaluation)

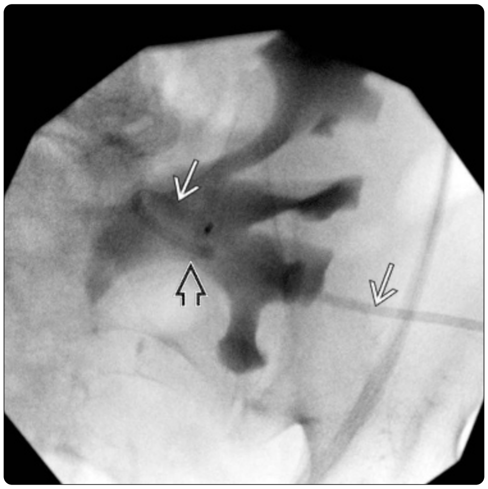


(Left) *Axial NECT of the left hemipelvis demonstrates an obstructing calculus ➡ in the proximal ureter of a renal transplant ⮕. Dilatation of the renal pelvis ↪ is evident, indicating hydronephrosis. Ureteral stenosis/ischemia is a more common cause of obstruction than calculus.* **(Right)** *Sagittal US prior to nephrostomy shows marked hydronephrosis ↪ in the transplant kidney. After selecting a lateral calyx for access, local anesthetic is administered using 1% lidocaine, and a dermatotomy is made with a #11 scalpel.*

Renal Transplant Urinary Obstruction (Fluoroscopy During Nephrostomy)



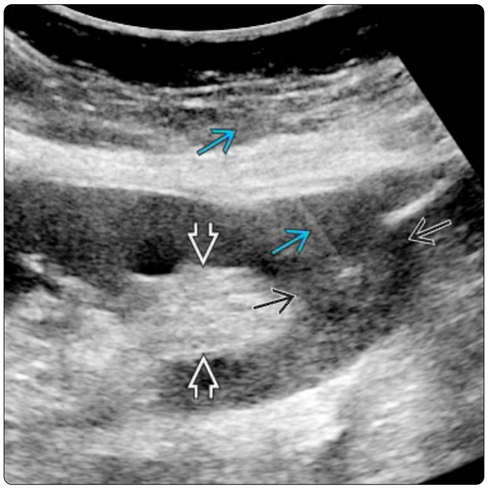
Renal Transplant Urinary Obstruction (Completion Nephrostogram)



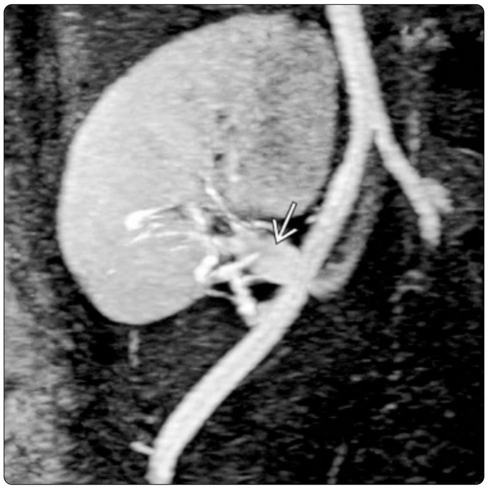
(Left) *Fluoroscopic spot image obtained during nephrostomy after contrast injection through the Chiba needle ⇨ confirms that the tip is in a lateral calyx ⤻. Nephrostomy catheter placement now will proceed using the 1-stick technique. The injected contrast volume is limited to reduce sepsis risk.* **(Right)** *Over the 0.035" guidewire, an 8-Fr pigtail nephrostomy catheter ➡ is advanced into the collecting system. Contrast injection confirms location within the renal pelvis ⇨.*

(Left) *US-guided percutaneous core biopsy of a pelvic transplant kidney displays desirable positioning and trajectory of the biopsy gun ⇨. Note the needle is located well within the lower pole renal cortex ⇨, oriented away from the hilum ➡.* **(Right)** *Despite adequate needle positioning, a postbiopsy arterial phase MRA shows premature filling of the renal vein ➡ from an arteriovenous fistula. Pseudoaneurysms and arteriovenous fistulas can occur due to renal biopsies.*

Acquired Arteriovenous Fistula (Nonfocal Renal Biopsy)

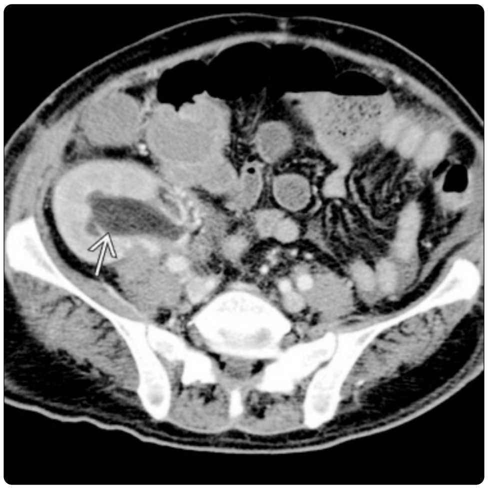


Acquired Arteriovenous Fistula (MRA Evaluation)

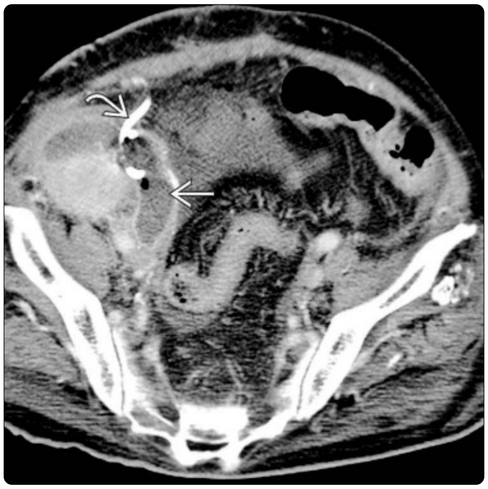


(Left) *Axial CECT demonstrates hydronephrosis ➡ of a right pelvic transplant kidney.* **(Right)** *More caudal image shows a perigraft fluid collection ➡, which was compressing the ureter (not shown). A percutaneous drainage catheter ↪ has been placed within the collection. The collection is loculated with gas bubbles within. This represents an abscess secondary to an infected lymphocele. Peritransplant fluid collections may come to clinical attention because of ureteral compression and resultant urinary obstruction.*

Perigraft Abscess Drainage (Associated Hydronephrosis)

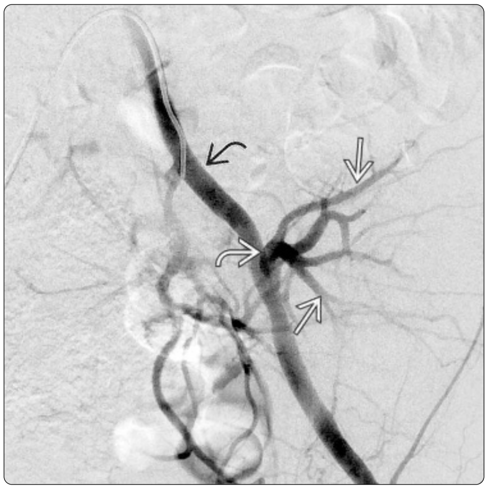


Perigraft Abscess Drainage (Drainage Catheter in Abscess)

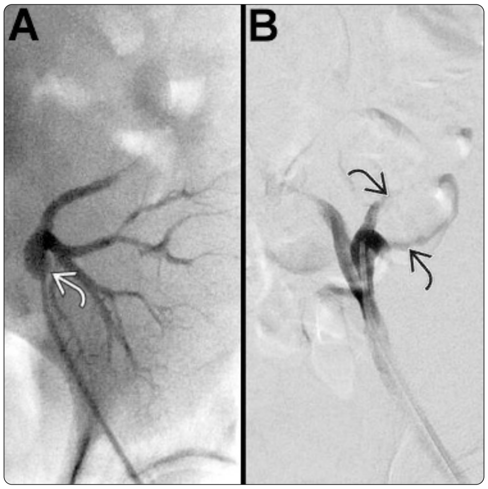


(Left) *DSA in a case of acute transplant rejection and severe hematuria shows a catheter in the left external iliac artery ↪. The transplant renal artery ↪ and intrarenal branches ➡ are patent, and no mass is seen.* **(Right)** *Transcatheter transplant ablation was performed before nephrectomy to control bleeding. (A) After placing a balloon occlusion catheter ↪ in the renal artery, contrast was injected, noting the volume used. (B) DSA after injecting a similar volume of alcohol shows nonfilling ↪ of branch vessels, c/w ablation.*

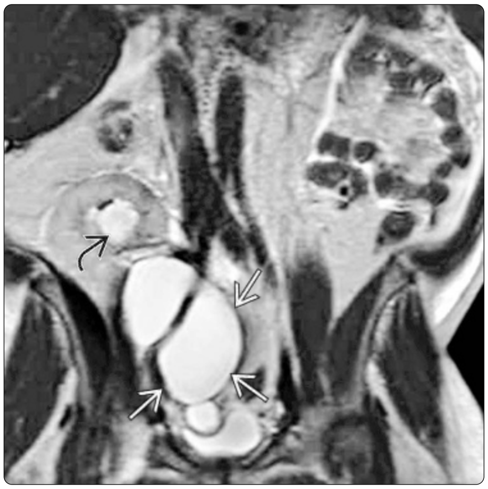
Ablation of Transplant Kidney (Diagnostic DSA Evaluation)



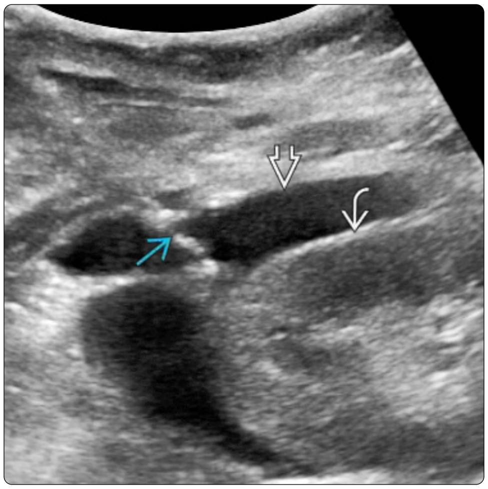
Ablation of Transplant Kidney (Embolization With Absolute Alcohol)



Sclerotherapy of Paragraft Lymphocele (Initial MR Evaluation)

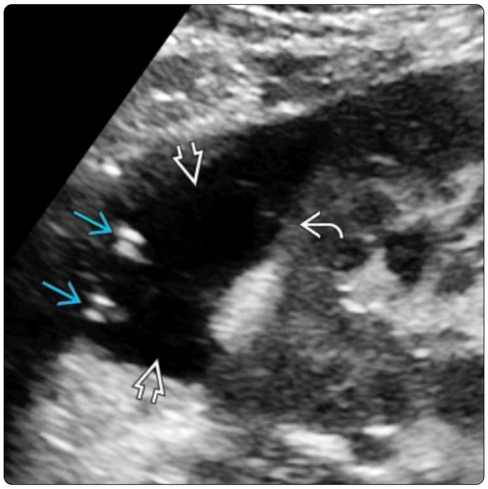


Sclerotherapy of Paragraft Lymphocele (US-Guided Drainage)

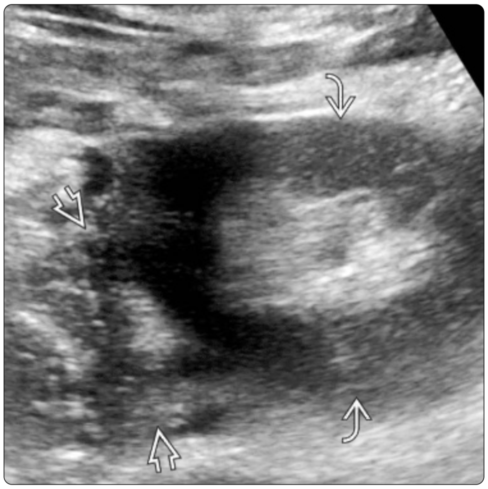


(Left) *Coronal T2WI MR shows hydronephrosis of the renal allograft* ↷ *caused by extrinsic ureteral compression from a surrounding lymphocele* → *with multiple septations.* **(Right)** *An 8-Fr locking pigtail catheter was loaded on a trocar* → *and advanced under real-time US-guidance into an anechoic collection* ⇨ *partially surrounding the transplant kidney* ↷*. Once the tip is in the collection, the hub is unscrewed, the inner trocar is held still, and the catheter is advanced further into the collection.*

Sclerotherapy of Paragraft Lymphocele (Persistence After Drainage)

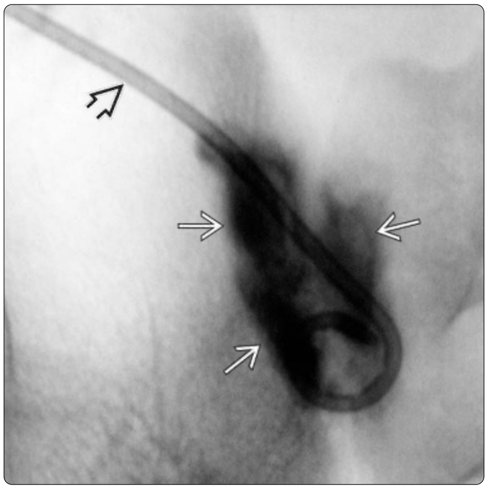


Sclerotherapy of Paragraft Lymphocele (Post Aspiration US)

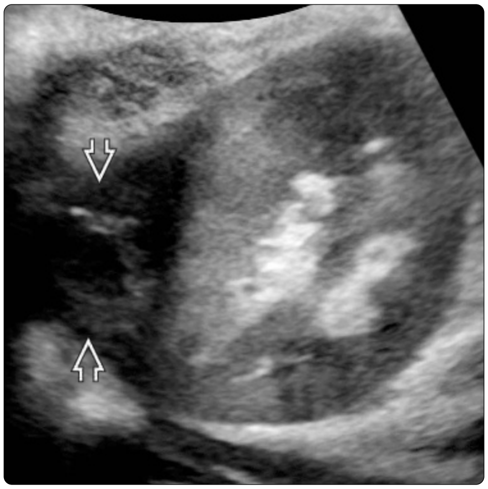


(Left) *One week after drainage, there was persistent fluid output from the catheter. US shows the pigtail loop* → *within a persistent collection* ⇨ *adjacent to the transplant kidney* ↷*. Lymphoceles are frequently refractory to drainage. Sclerotherapy is indicated in symptomatic cases.* **(Right)** *Lymphocele aspiration was performed. The collection* ⇨ *surrounding the transplant kidney* ↷ *is completely decompressed following aspiration, suggesting sclerotherapy from this location will involve the entire collection.*

Sclerotherapy of Paragraft Lymphocele (Sclerotherapy Preparation)



Sclerotherapy of Paragraft Lymphocele (Post Sclerotherapy)



(Left) *Contrast was injected via the drainage catheter* ⇨ *to exclude fistula to the collecting system and determine the potential volume of the cavity* →*. Sclerotherapy was subsequently performed by injecting 15 mL fibrin sealant into the lymphocele through the drainage catheter.* **(Right)** *Sagittal US obtained 1 week after sclerotherapy demonstrates interval collapse of the collection* ⇨*. The patient was pain free, there was no reaccumulation of lymphatic fluid, and hydronephrosis resolved.*

Transplant Liver Procedures

KEY FACTS

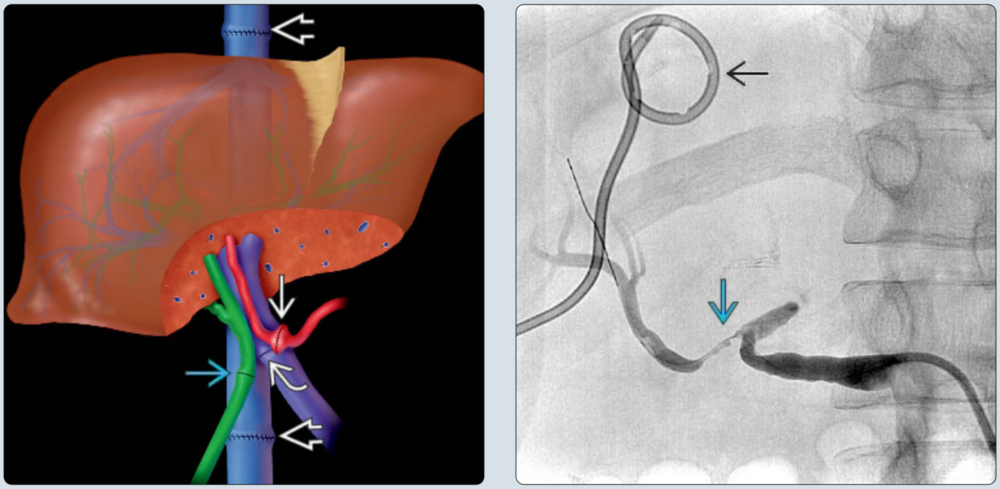
TERMINOLOGY

- **Orthotopic liver transplantation (OLT)**: Replacement of diseased native liver with donor allograft in same anatomic location; 4 separate anastomoses; well-recognized complications for each
- **Hepatic artery (HA) complications**: Most common posttransplantation vascular complication (5-25%)
  - Thrombosis: Most frequent arterial complication
  - Stenosis
  - Pseudoaneurysm (PSA)
  - Splenic steal syndrome
- **Inferior vena cava (IVC) & hepatic vein complications**
  - Anastomotic stricture or kink
- **Portal vein complications**
  - Stenosis & thrombosis
- **Biliary complications**
  - Stricture & bile leak

PROCEDURE

- **HA thrombosis**
  - Intraarterial thrombolysis, surgical thrombectomy
  - Address potential underlying HA stenosis
- **HA stenosis**
  - Angioplasty or stent for solitary focal stenosis; surgery preferred for other lesions
- **Splenic steal syndrome**
  - Treat with proximal splenic artery embolization
- **IVC & hepatic veins**
  - Treat with endovascular stenting (oversized)
- **Portal vein stenosis & thrombosis**
  - Thrombosis: Catheter-directed thrombolysis (CDT), possible stenting; anticoagulation necessary
  - Stenosis: Angioplasty ± stenting
- **Biliary stricture & leak**
  - Endoscopic vs. percutaneous (drainage, balloon dilation vs. stenting), surgical revision

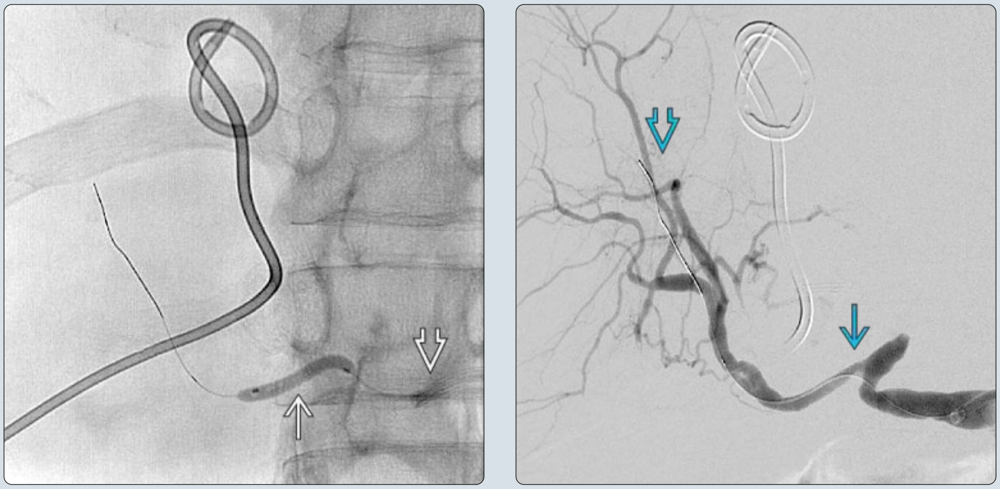
(Left) *Graphic shows postoperative anastomosis after orthotopic liver transplantation (OLT). Anastomoses involve hepatic artery* ➡*, common bile duct (CBD)* ⇨*, portal vein* ➡*, and inferior vena cava (IVC)* ➡*. Complications can involve any of these anastomoses.* **(Right)** *Five months after OLT, this patient was found to have a biloma, which was evacuated via a percutaneous transhepatic pigtail drain* ⇨*. Hepatic arteriogram reveals high-grade stenosis* ⇨ *of the donor-recipient anastomosis.*



Orthotopic Liver Transplantation

Hepatic Artery Stenosis: Initial Arteriogram

(Left) *Over a stiff shaft 0.014" microwire (GRAND SLAM, Abbott), and with a guide sheath* ➡ *advanced just proximal of the stenosis, angioplasty of the anastomosis was performed with a 4-mm diameter balloon* ➡*.* **(Right)** *Arterial flow to the liver* ⇨ *was now markedly improved, but moderate anastomotic stenosis remained* ⇨*. Slightly more aggressive 5-mm diameter angioplasty (not shown) was performed, completely resolving anastomotic narrowing. No stent placement was necessary.*



Hepatic Artery Stenosis: Angioplasty

Hepatic Artery Stenosis: Postangioplasty

TERMINOLOGY

Definitions

- **Orthotopic liver transplantation (OLT)**: Replacement of diseased native liver with donor allograft in same anatomic location
  - Different overall complication rates for living vs. deceased donor liver transplantation
    - Living donor transplantation: 10%
    - Deceased donor liver transplantation: 8%
  - OLT involves 4 anastomoses, each with well-recognized complications
    - Hepatic artery (HA) anastomosis
    - Portal vein anastomosis
    - Hepatic veins/inferior vena cava (IVC) anastomosis
    - Common bile duct anastomosis
- **HA complications**
  - Most common posttransplantation vascular complication (5-25%)
  - HA anastomosis: End-to-end, typically involving donor patch of aorta & recipient patch from HA bifurcation
  - Predisposing risk factors for complications
    - Donor age > 60 years, variant arterial anatomy/small arterial size, extended cold ischemia time, CMV-positive donor status, hypercoagulable state in recipient, recipient tobacco use, primary sclerosing cholangitis, rejection
  - Diagnostic evaluation: Typically start with Doppler US of HA (92% accuracy rate)
    - Normal: Continuous diastolic flow, sharp systolic upstroke; resistive index (RI) = 0.5-0.8
    - Abnormal: Absent diastolic flow, peak systolic velocity (PSV) > 200 cm/s, dampened & prolonged systolic upstroke (i.e., tardus parvus); RI < 0.5
  - **HA thrombosis**: Most frequent arterial complication (> 50%)
    - Incidence: 5% at 30 days; 19% at 1 year
      - Adult liver transplantation: 4-12% incidence
      - Pediatric liver transplantation: 40% incidence
    - Early (≤ 30 days) thrombosis: Retransplantation often required, mortality rate up to 58%
    - Late (> 30 days) thrombosis: 1/3 do well without intervention, others develop biliary necrosis/abscess
    - Treatment options (early & late)
      - Catheter-directed thrombolysis (CDT)
      - Underlying lesion may require angioplasty/stent
  - **HA stenosis**
    - Incidence: 5-13% of liver transplants
      - Median time to presentation: 3-7 months
      - Majority are anastomotic stenoses
    - Clinical signs & symptoms are variable
      - Asymptomatic, liver function test abnormalities, bile duct stricture, sepsis, acute liver failure
    - Untreated HA stenosis results in
      - 65% HA thrombosis rate at 6 months
      - 2x increase in biliary complication rate; abnormal cholangiogram in up to 67% of patients with HA stenosis
    - Treatment options
      - Angioplasty & stent placement
  - **HA pseudoaneurysm (PSA)**
    - Rare occurrence after liver transplantation
      - Most occur within 1st postoperative month
      - If extrahepatic may be mycotic, anastomotic
      - High mortality rate if untreated
    - Treatment options
      - Coil embolization, covered stent PSA exclusion
      - Surgical resection, retransplantation in some cases
  - **Splenic steal syndrome**
    - Nonocclusive arterial hypoperfusion of liver with preferential celiac flow to spleen
    - Incidence: 4.7%
    - Predisposing risk factor may include pre-OLT increased splenic volume
    - Clinical signs & symptoms
      - Elevated liver function tests, cholestasis, thrombocytopenia, ascites, graft failure
    - Diagnostic evaluation: Seen during celiac arteriography
    - Treatment option
      - Splenic artery embolization, possible splenectomy
- **IVC complications**
  - **Anastomotic stricture or kink**
    - Predisposing risk factors
      - Donor-to-recipient vessel size discrepancy, graft rotation, IVC kinking, tight suture
    - Effective treatment requires understanding of anastomotic anatomy used in transplant
      - Piggyback reconstruction: Preservation of recipient IVC with anastomosis of cuff formed from recipient hepatic veins to donor IVC; avoids intraoperative veno-veno bypass
      - End-to-side/end-to-end/cavoatrial anastomoses require intraoperative veno-veno bypass
    - Clinical signs & symptoms
      - Hepatic congestion, ascites, hepatomegaly, lower extremity edema, abnormal liver function texts, pleural effusion
    - Diagnostic evaluation: Typically start with Doppler US
      - Normal: Triphasic IVC & hepatic vein waveforms
      - Abnormal: Turbulent flow at stenosis; > 3:1 PSV anastomotic to preanastomotic segment
      - Confirmatory venography: IVC venous gradient > 10 mm Hg abnormal; gradient < 10 mm Hg can cause symptoms
    - Treatment options
      - Metal stents can provide long-term patency
      - Angioplasty less effective due to IVC elasticity
  - Caval obstruction: Incidence of 1-4%
  - Caval thrombosis: Incidence of 0.3%
- **Portal vein complications**
  - **Portal vein stenosis**
    - Incidence: 0.3-3.7%
    - Can occur in perioperative period or years later
    - Clinical signs & symptoms
      - Portal hypertension in symptomatic patients (e.g., ascites, gastroesophageal varices)
      - Majority asymptomatic; detected on screening
    - Diagnostic evaluation
      - Typically start with Doppler US

      - Normal: Monophasic with respiratory variation
      - Abnormal: PSV > 125 cm/s; > 3:1 PSV anastomotic to preanastomotic segment
      - Confirmatory transhepatic portography: > 5 mm Hg pressure gradient significant for stenosis
    - Treatment options
      - Angioplasty ± stent placement
  - **Portal vein thrombosis (PVT)**
    - Incidence: 3-7%
      - Can be fatal for transplant & patient
    - Predisposing risk factors
      - Small portal vein size (< 5 mm), PVT noted at transplantation, reconstruction with venous conduit, prior splenectomy, redundancy, or tension of portal vein anastomosis
    - Treatment options
      - CDT (if thrombus detected early), stenting
      - Anticoagulation necessary; surgical thrombectomy should be considered
- **Biliary complications**
  - Overall incidence: 23%
  - Biliary anastomosis: 2 potential types
    - Choledochocholedochostomy (ideally, donor common bile duct to recipient common hepatic duct)
    - Choledochojejunostomy: Used when recipient duct too short, narrow, or diseased (e.g., sclerosing cholangitis); donor to recipient duct size mismatch
  - **Biliary strictures**
    - Anastomotic strictures: Incidence 15%
    - Nonanastomotic strictures: Incidence 5-15%
      - Often multiple strictures present
      - Can result in transplant loss of 46% after 2 years
    - Predisposing risk factors
      - HA thrombosis, CMV infection, model of end-stage liver disease score > 25, primary sclerosing cholangitis, malignancy, donor age > 60, macrovesicular graft steatosis, duct-to-duct anastomosis, cold ischemic time > 12 h, use of T-tube, acute rejection
    - Clinical signs & symptoms
      - Fever, abdominal pain, jaundice, elevated liver function tests
    - Diagnostic evaluation
      - MRCP, cholangiogram
    - Usually occur within 5-8 months after transplant
    - Treatment options
      - Endoscopic vs. percutaneous drainage
      - Balloon dilation
      - Stenting (metallic covered retrievable vs. plastic)
      - Surgical revision
  - **Bile leak**
    - Incidence: 8.5%, (reported range: 1-25%)
    - Typically occur within 1-3 months
    - Most occur at anastomosis or T-tube insertion site
      - T-tube use for biliary anastomosis stenting is associated with bile leak & cholangitis at removal
      - Routine T-tube use abandoned in many centers
    - Clinical signs & symptoms
      - Fever, abdominal pain, peritonitis
    - Diagnostic evaluation
      - Nuclear scintigraphy, cholangiography, aspiration of biloma
  - **Bile duct stones, sludge, & casts**
    - Relatively infrequent compared to leaks & strictures
    - Predisposing risk factors
      - Ischemia, infection, postoperative bile duct edema, CMV cholangitis
  - Treatment: Endoscopic, percutaneous, or surgical

PREPROCEDURE

Indications

- **General**
  - Unexplained increasing ascites; allograft disfunction
  - Elevated liver enzymes, unexplained sepsis, jaundice
- **HA abnormalities**
  - HA stenosis
    - Percutaneous transluminal angioplasty (PTA)
      - Solitary focal HA stenosis
      - Surgery preferred for other lesions (e.g., tandem stenoses, arterial "kinking") unless operative risk
    - Intravascular stent placement
      - Lesion refractory to PTA or post-PTA restenosis
  - HA PSA
    - PSA embolization or exclusion
  - HA thrombosis
    - CDT
- **IVC abnormalities**
  - Stenosis causing ascites or lower extremity swelling
- **Portal vein abnormalities**
  - Portal vein stenosis/thrombosis
    - Accompanying portal hypertension symptoms (e.g., variceal hemorrhage, ascites, splenomegaly)
    - May require CDT, angioplasty, & stenting
- **Biliary tract abnormalities**
  - Fever, abdominal pain, jaundice

Contraindications

- **General**
  - Uncorrectable coagulopathy
  - Anaphylaxis to radiographic contrast
- **Arterial or venous thrombosis**
  - Perioperative thrombolysis may be problematic
- **Portal vein interventions**
  - Ascites is relative contraindication
    - Should be drained before percutaneous access
      - Reduces risk of postprocedural bleeding

Preprocedure Imaging

- Doppler US
  - **HA thrombosis**
    - Absent porta hepatis/intrahepatic arterial signal
  - **HA stenosis**
    - Peak systolic velocities > 200 cm/s
    - Focal increase in velocity > 3x adjacent area
    - RI < 0.5
    - Systolic acceleration time > 0.08 seconds (tardus-parvus pattern)
  - **IVC, portal/hepatic vein thrombosis or stenosis**
    - Venous thrombosis
      - No identified flow; intraluminal filling defect(s)

    - Venous stenosis
      - Narrowing ± ↑ velocity
  - Doppler US surveillance essential for early detection of posttransplantation complications
- Perform CT/MR to evaluate questionable cases
  - CTA for overall evaluation of posttransplantation vascular complications
    - Sensitivity/specificity: 87 & 90%, respectively
  - CT & MR are highly accurate in detecting PVT & stenosis (> 50%)
    - 100% sensitivity for thrombosis; 84% for stenosis

Getting Started

- Things to check
  - Clinical history & physical examination
    - Review transplantation operative report
      - Confirm anastomosis types/locations
  - Current medications
    - Any anticoagulants, antiplatelet agents
  - Allergies
  - Laboratory parameters
    - Electrolytes, glomerular filtration rate (eGFR)
      - Prefer normal Cr; eGFR > 60; otherwise consider using CO_2 rather than iodinated contrast
    - Liver function tests
    - Complete blood count
      - Platelet count > 50,000/µL
    - Coagulation profile
      - International normalized ratio (INR) ≤ 1.5
- Medications
  - Heparin for intraarterial intervention
    - 2,000-5,000 units given as bolus
  - Intraarterial vasodilator (e.g., nitroglycerin)
    - Typical bolus dose of 100 µg of nitroglycerin
  - Thrombolytic agent (e.g., alteplase)
    - For treatment of arterial & venous thrombosis
- Equipment list
  - Guidewires
    - Initial 0.035" guidewire
    - Hydrophilic guidewire
    - 0.014-0.018" microwire
    - Stiff guidewire (e.g., Rosen, McNamara)
  - Catheters & sheaths
    - 5- to 6-Fr arterial access sheath
    - Flush catheter (e.g., pigtail, Omni Flush)
    - Selective catheter (e.g., Cobra-2)
    - Guiding catheter/sheath; permits contrast injection around stent during placement
    - Microcatheter
  - Angioplasty (PTA) balloons
    - Match balloon & lesion lengths
      - HA: Low-profile 0.014-0.018" system; 3- to 6-mm balloon diameters
      - Portal vein: 10- to 20-mm balloon diameter
      - IVC & hepatic veins: 14- to 24-mm balloon diameter
    - Over-the-wire vs. rapid-exchange system
  - Intravascular stents
    - HA: Prefer high radial force balloon-mounted stent; typically 3- to 6-mm diameter
    - Portal/hepatic veins, IVC
      - Various proprietary noncovered self-expanding/balloon-mounted stents [e.g., Wallstent (Boston Scientific; Natick, MA)]
      - Covered self-expanding or balloon-mounted stents
  - Pharmacomechanical thrombolysis equipment
    - Possis AngioJet (Medrad; Warrendale, PA)
    - EkoSonic catheter system (Ekos; Bothell, WA)
    - 4- to 5-Fr multiple sidehole infusion catheters
  - Percutaneous transhepatic access needle & sheath
    - Chiba needle (22 gauge)
    - Neff access set (Cook Medical; Bloomington, IN)
      - Initial puncture with 22-gauge needle allows introduction of 0.018" guidewire
      - Coaxial introducer advanced over guidewire
      - Introducer/stiffening cannula removal allows 0.035" guidewire introduction via sheath

PROCEDURE

Procedure Steps

- **Angioplasty & stenting**
  - **HA**
    - Sterilely prepare & drape intended access site
    - Obtain arterial access; place access sheath
    - Place selective (reverse-curve) catheter in celiac artery; obtain DSA
    - Advance guiding catheter to common HA
      - Introduce coaxial catheter/microcatheter; place proximal to stenosis
    - Administer heparin prior to crossing stenosis
    - Cross stenosis with floppy tip microwire
      - Confirm position with DSA via guiding catheter
    - Advance microcatheter beyond stenosis
      - Inject contrast, confirm position
      - Exchange for stiff guidewire prior to PTA
    - Replace microcatheter with PTA balloon
      - Measure normal vessel diameter with electronic calipers; size balloon accordingly
      - Avoid oversizing balloon (risk of vessel rupture)
      - Typically begin with 3- to 4-mm diameter balloon, inflate to nominal pressure
    - Obtain postangioplasty DSA via guiding catheter
      - Consider upsizing balloon if unchanged or proceed to stent placement (balloon mounted)
  - **IVC & hepatic veins**
    - Obtain right internal jugular venous access; some operators prefer femoral vein access
      - Place vascular access sheath & guidewire
    - Place 5-Fr pigtail catheter over guidewire into IVC
    - Obtain pressure measurements in IVC
      - Evaluate for infra- to suprahepatic IVC gradient
      - Gradient ≥ 8-10 mm Hg significant
    - Position catheter just below venous anastomosis
      - Inject contrast; obtain DSA
    - May need selective hepatic venography to evaluate venous outflow from liver
    - If IVC stenosis identified, treat with angioplasty
      - Place stiff 0.035" Amplatz guidewire
      - Perform angioplasty with large-diameter balloon

    - Following angioplasty, perform DSA; obtain repeat IVC pressure measurements
    - If residual stenosis on DSA or persistent gradient, proceed to intravascular stent placement
    - Oversize self-expanding stent to prevent migration
      - ☐ Post dilate self-expanding stent to anchor
    - Balloon-mounted stent placement may be more precise; less chance for migration
    - Individual hepatic vein stenoses can be also treated with PTA or stenting
  - **Portal vein**
    - Sterilely prepare & drape intended access site
      - ☐ Typically right midaxillary line for percutaneous transhepatic access
    - Obtain percutaneous access into portal vein
      - ☐ May use US or fluoroscopic guidance
      - ☐ Confirm with aspiration & contrast injection
    - Introduce vascular access sheath into portal vein
      - ☐ Inject contrast, confirm position
    - Advance coaxial catheter via sheath, obtain DSA
      - ☐ Confirm & localize portal vein stenosis
    - Cross stenosis with 0.035" Glidewire (Terumo Medical)
      - ☐ Advance catheter over Glidewire beyond stenosis
    - Exchange for stiff guidewire (e.g., Amplatz, Rosen)
    - Introduce angioplasty balloon, position at stenosis
      - ☐ Typically use 8- to 12-mm balloon
    - Perform angioplasty; use insufflator
    - Perform postangioplasty DSA
      - ☐ Place stent if stenosis remains
- **Thrombolysis**
  - **Arterial**
    - Selectively catheterize HA
      - ☐ Advance guidewire & catheter across thrombus
    - Place infusion catheter; initiate thrombolysis
      - ☐ Consider initial pulse-spray of thrombolytic (e.g., 5-10 mg tPA)
      - ☐ Perform clinical & biochemical monitoring of fibrinogen, INR, & liver enzymes q 4 h
    - Check thrombolysis progress at least every 12 h with DSA imaging
      - ☐ Continue thrombolysis for 48-72 h if clinical/angiographic improvement
    - Stop thrombolysis if no significant difference for 12 h or if bleeding complications occur
    - If successful thrombolysis, evaluate for any underlying cause of HA thrombosis
      - ☐ Treat any stenosis with angioplasty or stent
  - **Portal vein**
    - Similar thrombolytic technique, described above
- **Biliary drainage & other biliary interventions**
  - Described in depth in alternate nontransplant chapters

Alternative Procedures/Therapies

- Vascular abnormalities
  - Surgical revascularization
- Biliary leak or anastomotic stricture
  - Surgical repair
  - Endoscopic retrograde cholangiopancreatography with endoscopic intervention
- Retransplantation: Traditional treatment of choice

OUTCOMES

Complications

- Most feared complication(s)
  - Vessel rupture/thrombosis during angioplasty
  - Stent migration to right atrium during IVC treatment
- Immediate/periprocedural complication(s)
  - Angioplasty: Complications in up to 9%
    - Arterial dissection, thrombosis, PSA
  - Stent placement: Thrombosis, distal migration
  - Thrombolysis: Bleeding complications
  - Access site complications (e.g., hematoma, PSA)
- Delayed complication(s)
  - HA restenosis
    - Occurs in 30-60% of cases after treatment

Expected Outcomes

- HA thrombosis
  - Technical success: 68%
  - Need for additional procedures (e.g., balloon angioplasty &/or stenting): 62%
- HA stenosis
  - Technical success: 81%
  - Failures typically due to inability to cross lesion; HA tortuosity
  - Post-PTA & poststent restenosis rates: 30%
  - Primary restenosis recurrence intervals
    - Post-PTA: 2.7 months
    - Poststenting: 5.3 months
- Splenic steal syndrome: Limited data
  - Improved liver function tests in 96% of cases following splenic artery embolization
- IVC & hepatic veins: Limited data
  - One report of 100% primary stent patency (average: 491 days)
- Portal vein
  - Stenosis: 70% success rates following stenting
  - Thrombosis: 40% success rate; 33% 1-year graft survival
- Biliary stricture
  - Endoscopic vs. percutaneous drainage
    - Stents typically have ↓ treatment duration but ↓ clinical success vs. indwelling drainage catheters: Similar complications rates
    - Plastic stents may have ↑ complications, ↓ stricture resolution vs. metallic covered stents
  - PTA dilation: Requires multiple treatments, up to 1 year

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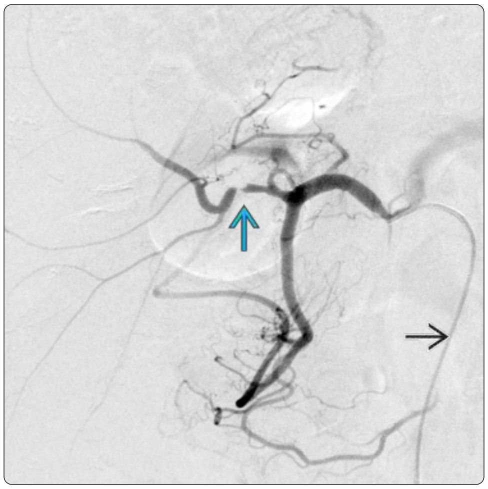
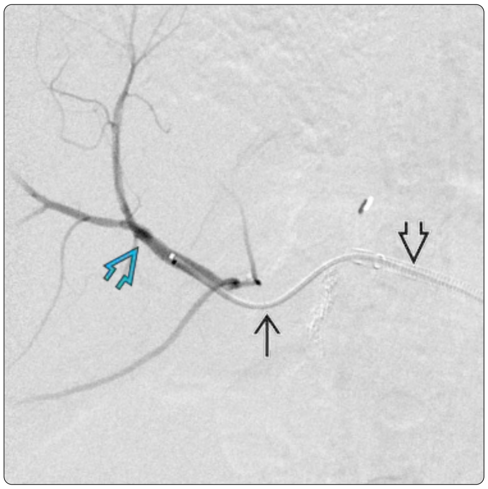
5. Ayoub WS et al: Biliary complications following liver transplantation. Dig Dis Sci. 55(6):1540-6, 2010
6. Singhal A et al: Endovascular treatment of hepatic artery thrombosis following liver transplantation. Transpl Int. 23(3):245-56, 2010

Hepatic Artery Stenosis: Initial DSA Evaluation

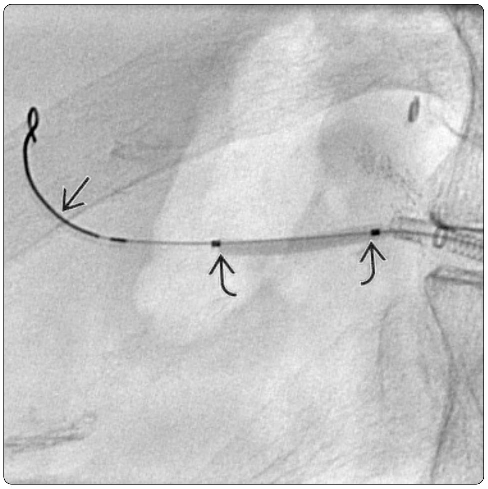


Hepatic Artery Stenosis: Microcatheter Across Stenosis

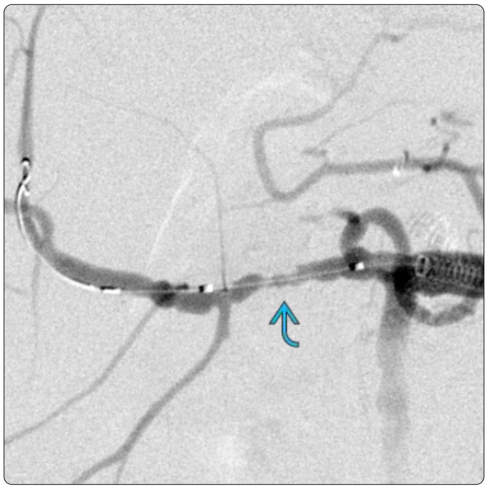


(Left) *A common hepatic artery DSA via a Cobra catheter →, in a patient who presented with acute hepatic failure 3 weeks after orthotopic liver transplant, shows a focal solitary high-grade hepatic artery stenosis → at the surgical anastomosis.* **(Right)** *A guiding sheath ⇨ was positioned proximal to the stenosis. A microwire and microcatheter → were carefully advanced across the stenosis. DSA shows a patent and unremarkable right hepatic artery ⇨ distal to the stenosis.*

Hepatic Artery Stenosis: Angioplasty of Stenosis

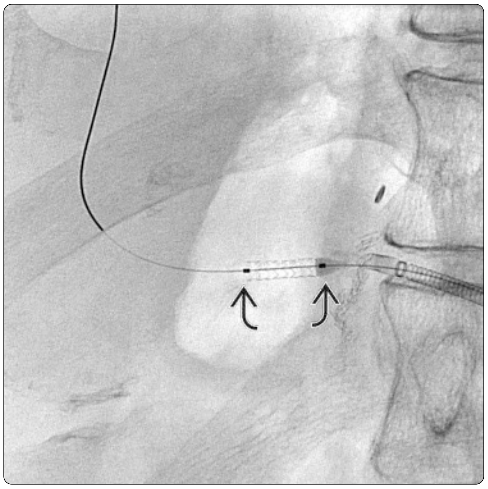


Hepatic Artery Stenosis: Residual Stenosis After Angioplasty

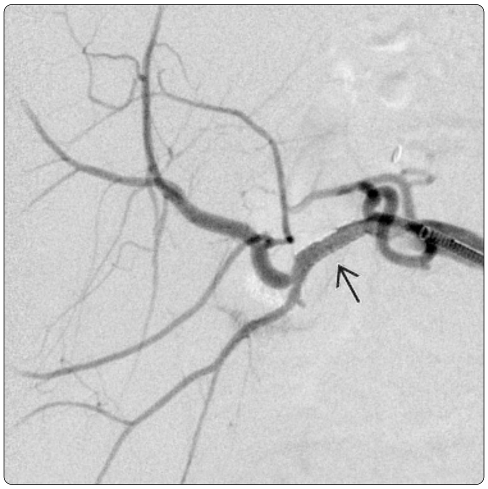


(Left) *After placing the microcatheter across the stenosis, the floppy tip microwire used initially was replaced with a stiffer guidewire →. The microcatheter was removed, and an angioplasty catheter was introduced. The balloon ↪ was centered at the stenosis, as confirmed with contrast via the sheath, and angioplasty was performed.* **(Right)** *Postangioplasty DSA, via the guiding sheath, shows there has been only minimal improvement in the stenosis, and there is a very irregular appearance ↪ to the artery.*

Hepatic Artery Stenosis: Intravascular Stent Placement



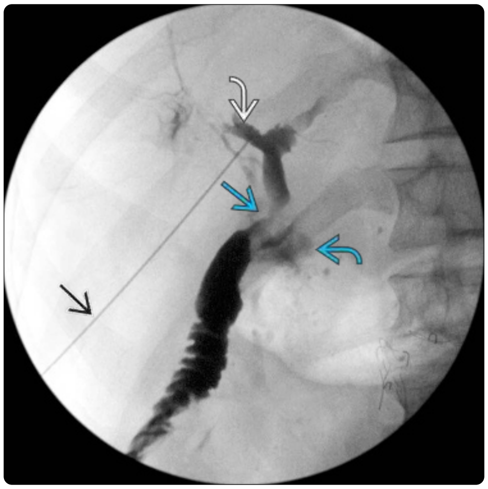
Hepatic Artery Stenosis: Poststent Placement (Final Hepatic Arteriogram)



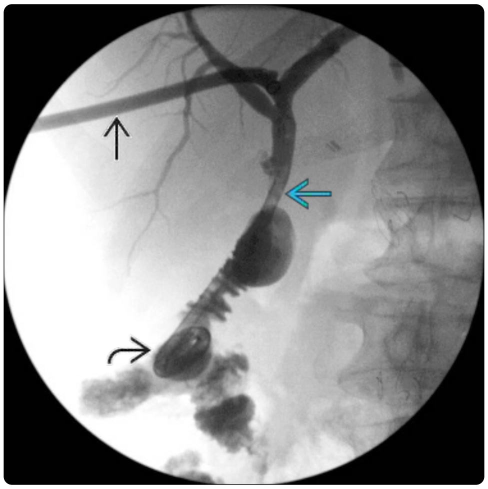
(Left) *Intravascular stent placement was felt to be indicated, given the postangioplasty appearance of the hepatic artery. The guidewire was left indwelling, and the angioplasty catheter was replaced with a balloon-mounted stent. A spot radiograph shows the inflated balloon deploying the stent ↪.* **(Right)** *DSA after stent placement shows a satisfactory stent position → and a normal luminal caliber. By report, 65% of untreated posttransplant hepatic artery stenoses will progress to thrombosis at 6 months.*

(Left) *This patient presented with abdominal pain and fever 1 month after liver transplantation. Cholangiography shows the access needle → in the dilated right main biliary duct →. There has been a choledochojejunostomy. An anastomotic stricture → and a biliary leak → are seen.* **(Right)** *A percutaneous transhepatic biliary drainage catheter → has been placed across the stricture → into the jejunum →. Decompressing the stricture promotes spontaneously sealing of the leak.*

Biliary Anastomotic Stricture and Leak (Transhepatic Cholangiography)

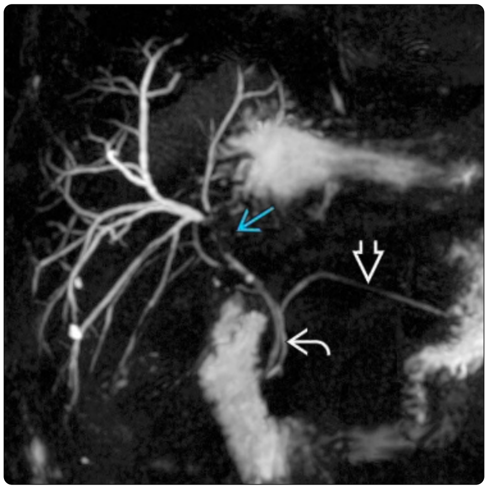


Biliary Anastomotic Stricture and Leak: Percutaneous Drainage Catheter

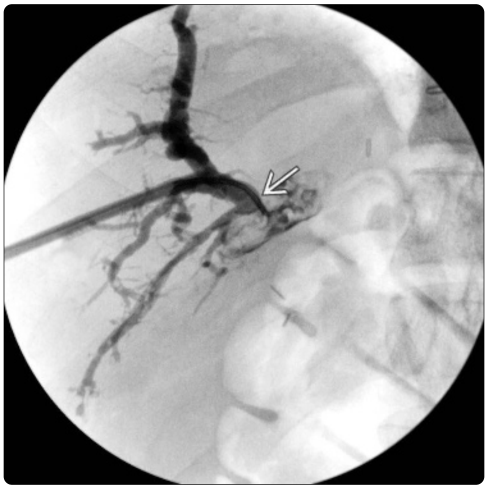


(Left) *MRCP in a patient with onset of fever, abdominal pain, and jaundice 6 months after liver transplant shows signal absence → in the proximal CBD, representing severe stricture or occlusion. The distal CBD → and pancreatic duct → are patent.* **(Right)** *Following failed ERCP, percutaneous transhepatic cholangiography was performed, and a catheter → was advanced to the anastomosis. The catheter would not cross, therefore a drainage catheter was left in place.*

Anastomotic Biliary Stricture: Initial Imaging (MRCP Evaluation)

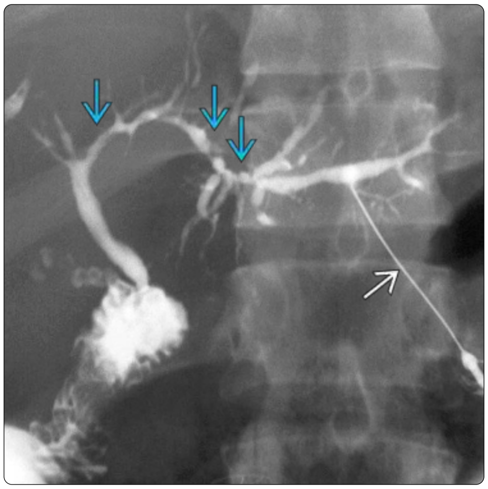


Anastomotic Biliary Stricture: Drain Placement (Transhepatic Cholangiography)

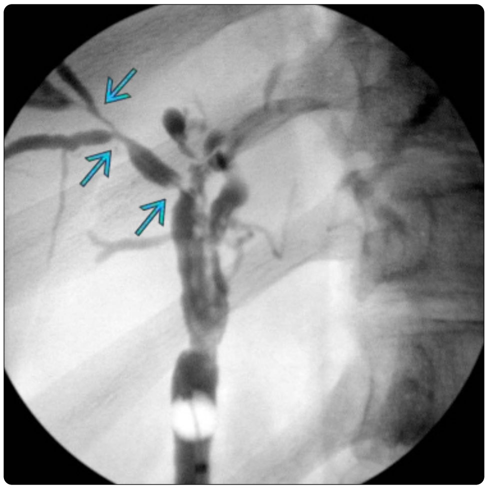


(Left) *Cholangiography shows access → to the left biliary ductal system. Multiple strictures → are in a nonanastomotic distribution. Such strictures may result from bile duct ischemia due to hepatic artery compromise, but other processes (e.g., rejection, recurrent cholangitis) may also be causative.* **(Right)** *Multifocal nonanastomotic strictures → are seen during ERCP. Treatment of these lesions with balloon dilatation or stenting may require both endoscopic and percutaneous intervention.*

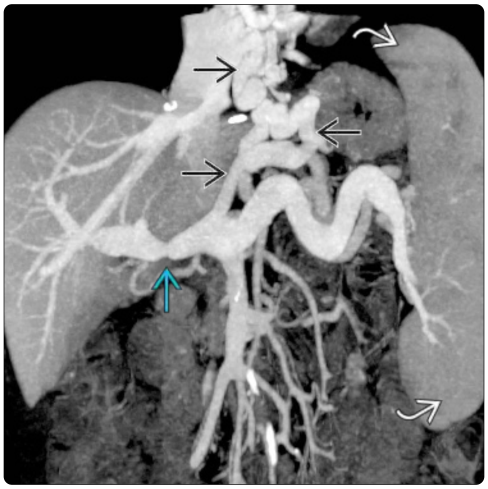
Nonanastomotic Biliary Strictures (Transhepatic Cholangiography)



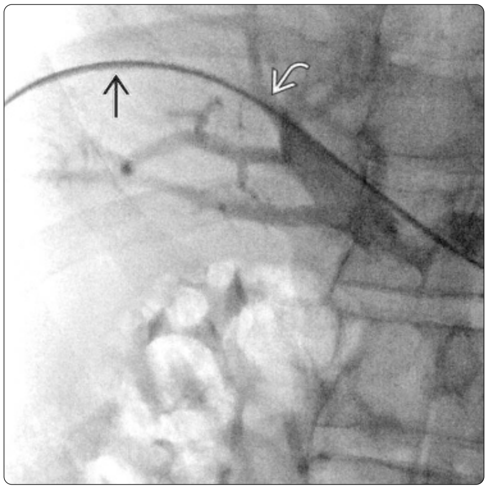
Nonanastomotic Biliary Strictures: Endoscopic Management (ERCP)



Anastomotic Portal Vein Stenosis: Initial Diagnostic Imaging (CT Venography)

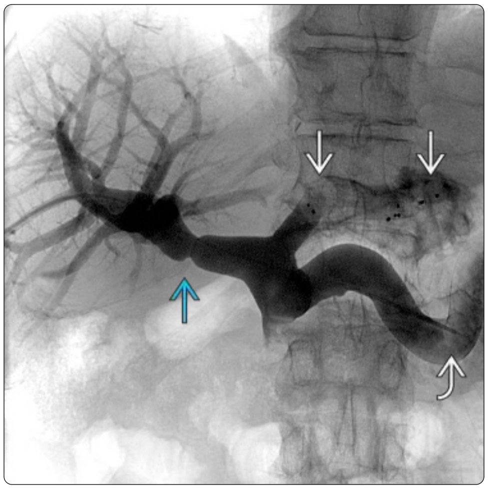


Anastomotic Portal Vein Stenosis: Percutaneous Transhepatic Access

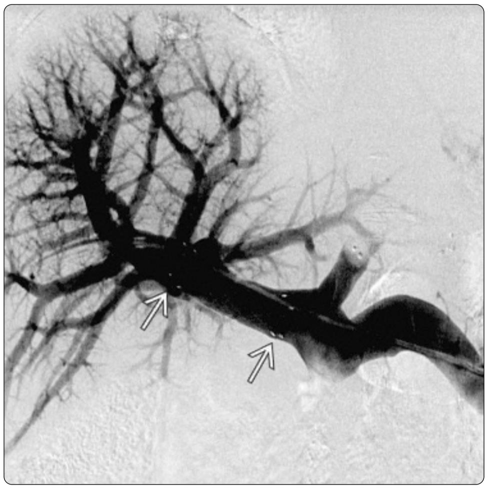


(Left) *A patient presented with ascites and hematemesis 8 months after an orthotopic liver transplant. CECT reveals high-grade anastomotic stenosis of the main portal vein →. This has resulted in extensive gastroesophageal varices → and splenomegaly ↪.* **(Right)** *Percutaneous transhepatic portal vein access was obtained, and a vascular sheath and catheter were introduced. Contrast was injected to confirm catheter position. The catheter → can be seen entering a right portal vein branch ↪.*

Anastomotic Portal Vein Stenosis: Variceal Embolization (Portal Venography)

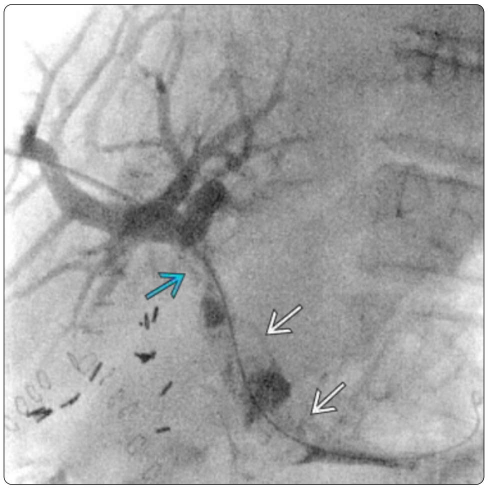


Anastomotic Portal Vein Stenosis: Stent Deployment (Portal Venography)

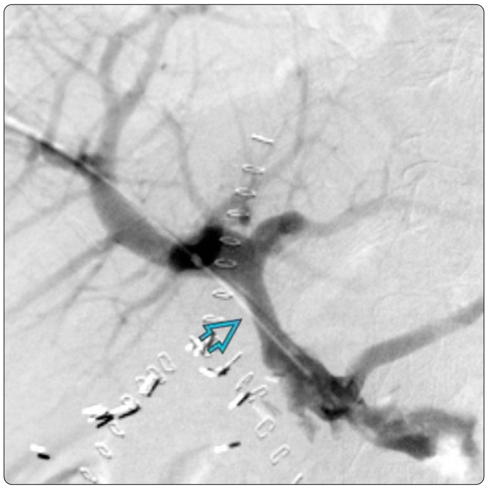


(Left) *After gaining portal vein access, transcatheter embolization of the large gastroesophageal varices was performed using plug occluding devices ➡. Afterward, a portal venogram (via a catheter with the tip ↪ in the splenic vein) shows nonfilling of the varices and confirms the severe portal vein stenosis →.* **(Right)** *Stenosis was treated by placing a 14-mm diameter x 40-mm long self-expanding stent. DSA portography obtained afterward shows the stent ➡ in satisfactory position with no residual stenosis.*

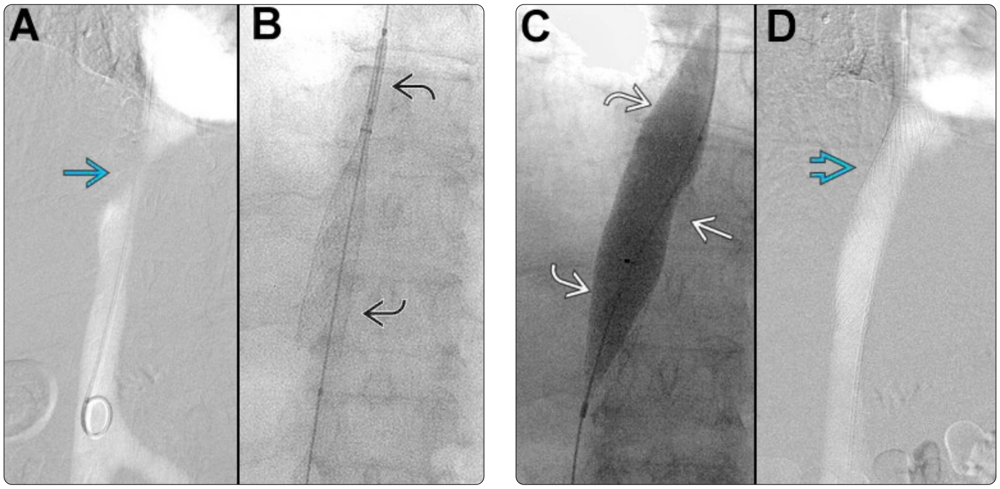
Portal Vein Thrombosis: Initial Imaging (Transhepatic Portal Venogram)



Portal Vein Thrombosis: Posttreatment (Transhepatic Portal Venogram)



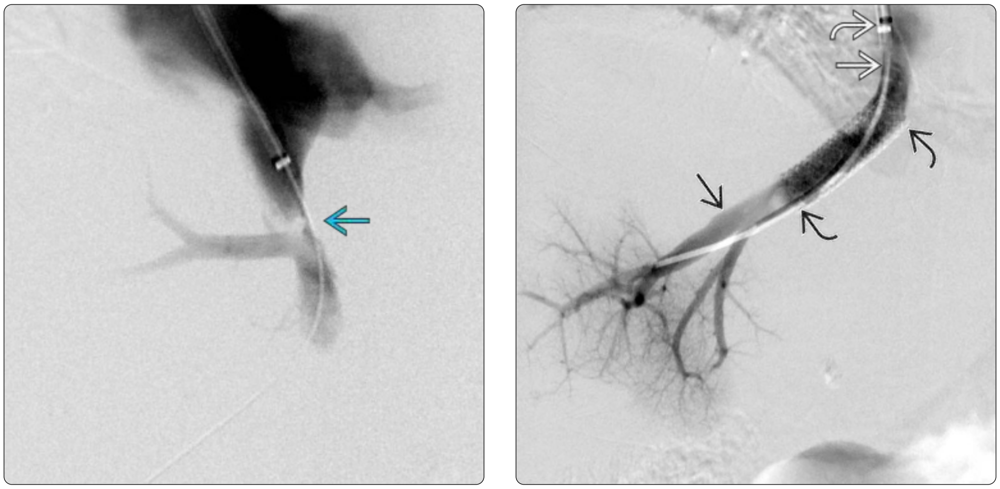
(Left) *Transhepatic portal venography shows a severe portal vein stenosis → and multiple intraluminal filling defects ➡ consistent with portal vein thrombosis. Posttransplant portal vein thrombosis can result in transplant loss or may be fatal.* **(Right)** *Catheter-directed thrombolysis was successful in clearing the thrombus, and this was followed by angioplasty and stenting. Subsequently, DSA shows a patent portal vein with an improved caliber ⇨.*



IVC Anastomotic Stenosis: Initial Imaging and Stent Deployment (CO₂ Cavography)

IVC Anastomotic Stenosis: Angioplasty (Completion DSA)

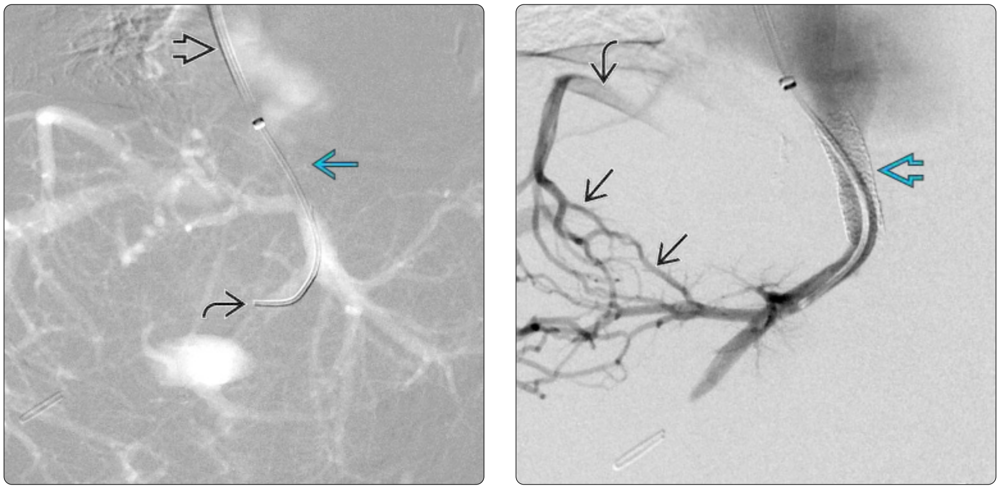
(Left) *This patient had onset of worsening ascites, bilateral lower extremity swelling, renal dysfunction, and elevated liver enzymes months after liver transplantation. (A) CO₂ venacavography shows an intrahepatic IVC stenosis →. As this was unresponsive to angioplasty, (B) a stent ⇨ was placed.* **(Right)** *(C) After stent placement, a large-diameter PTA balloon ➡ was used to distend the stent. A "waist" ➡ in the balloon denotes the IVC stenosis. (D) Repeat CO₂ venacavography after stenting and angioplasty shows no residual IVC stenosis ⇨.*



Hepatic Vein Stenosis: Initial Imaging (Venacavography)

Hepatic Vein Stenosis: Stent Deployment (Hepatic Vein DSA)

(Left) *The "piggyback" IVC reconstruction technique seen here involves leaving the recipient's retroperitoneal IVC intact and creating a cuff from the recipient's hepatic veins. This is anastomosed to the donor suprahepatic IVC, thus altering IVC anatomy and sometimes causing stenoses →, as seen in this DSA.* **(Right)** *Selective hepatic venous → DSA via a guiding sheath ➡ and angled catheter ➡ shows that a balloon-mounted stent ⇨ has been placed and has eliminated the venous stenosis.*

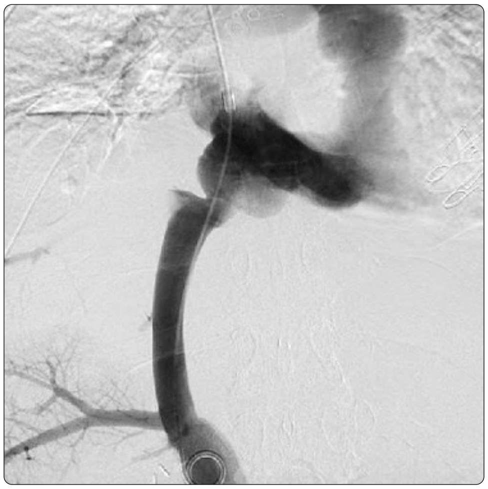


Hepatic Vein Stenosis: Initial Imaging (Hepatic Venogram With CO₂)

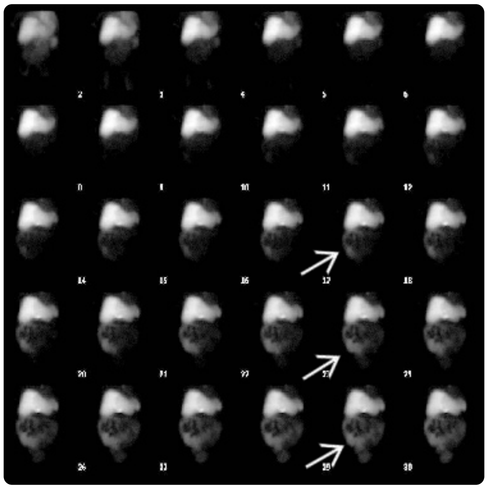
Hepatic Vein Stenosis: Poststenting (Hepatic Venography)

(Left) *Left hepatic venography shows a Cobra catheter ⇨ coaxially introduced into the left hepatic vein via a guiding sheath ⇨. There is no contrast identified in the proximal left hepatic vein →, where a severe stenosis is present.* **(Right)** *A balloon-mounted stent ⇨ was placed across the left hepatic vein stenosis. A repeat DSA using iodinated contrast shows elimination of the venous stenosis. Note that intrahepatic venous communications → are also seen partially filling the right hepatic vein ⇨.*

Early Post-OLT Complications (Venocavogram and Pressure Measurements)

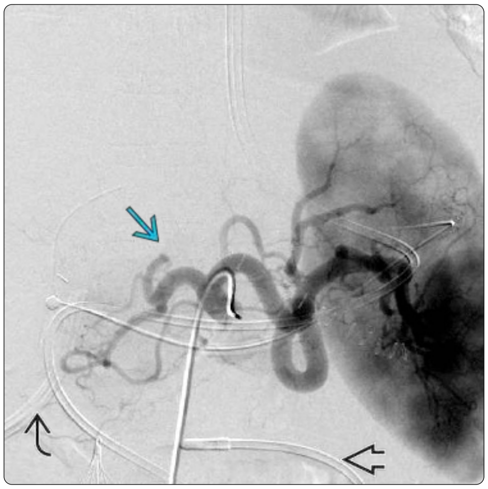


Early Post-OLT Complications

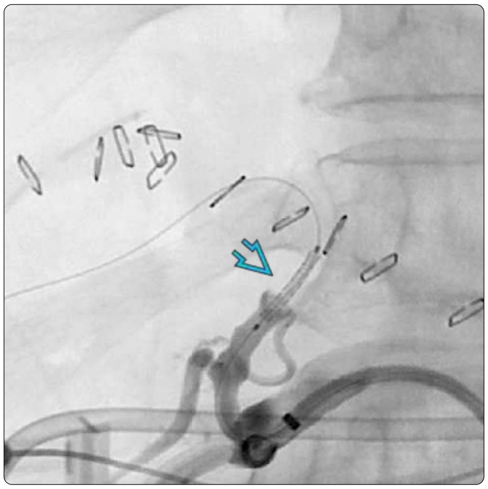


(Left) *A 62-year-old woman 3 weeks out from OLT developed elevated liver function tests, new-onset ascites, and bilateral DVTs. An IVC filter was placed. Doppler US reported possible IVC anastomotic narrowing and hepatic artery low-resistance waveforms. A cavogram shows < 30% narrowing of the venovenous anastomosis, with 6 mm Hg pressure gradient. Endovascular IVC treatment was not indicated.* **(Right)** *A hepatobiliary scan revealed radiotracer in the extraluminal right paracolic gutter* ➡*, consistent with a biliary leak.*

Early Post-OLT Complications: Hepatic Artery Anastomotic Occlusion (Celiac DSA)

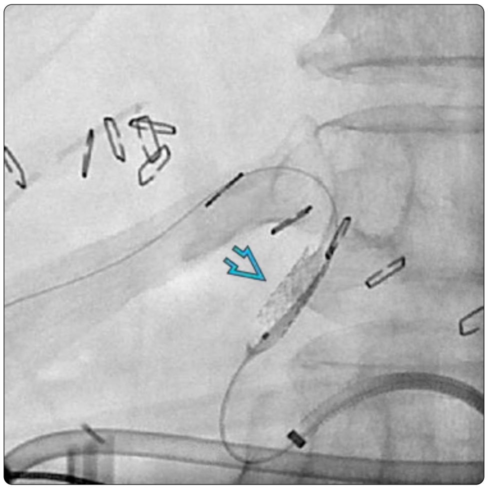


Early Post-OLT Complications: Positioning Balloon Expandable Stent

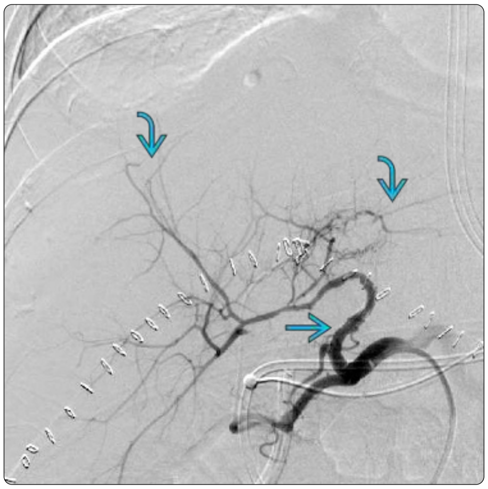


(Left) *A subhepatic drain* ⇨ *and nasojejunal feeding tube* ⇨ *were placed. The patient continued to deteriorate. Repeat Doppler ultrasonography now revealed absence of hepatic arterial flow. Celiac arteriography was performed, confirming total occlusion at the hepatic artery anastomosis* ⇨*.* **(Right)** *A floppy tip hydrophilic microwire traversed the hepatic artery anastomosis and was then exchanged for a stiffer nonhydrophilic microwire. A balloon expandable stent* ⇨ *was positioned at the anastomosis.*

Early Post-OLT Complications: Stent Deployment at Anastomosis



Early Post-OLT Complications: Arterial Flow Restored (Hepatic Arteriogram)



(Left) *The balloon expandable stent* ⇨ *was deployed.* **(Right)** *Arterial flow did not immediately return until intraarterial tPA (4 mg) and nitroglycerin (300 mcg) were delivered via a microcatheter advanced into the donor hepatic artery. Although the hepatic artery anastomosis* ⇨ *was now patent, allowing flow into the distal intrahepatic branches* ⇨*, biliary ischemia had already occurred. Shortly hereafter, the patient required intrahepatic biliary drains and ultimately went on to retransplantation.*

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SECTION 7

Nonvascular Procedures

General Considerations

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Biopsy Procedures

KEY FACTS

TERMINOLOGY

- Nonfocal (random) biopsy: Biopsy of organ parenchyma to assess diffuse disease
- Focal (targeted) biopsy: Biopsy of discrete lesion

PREPROCEDURE

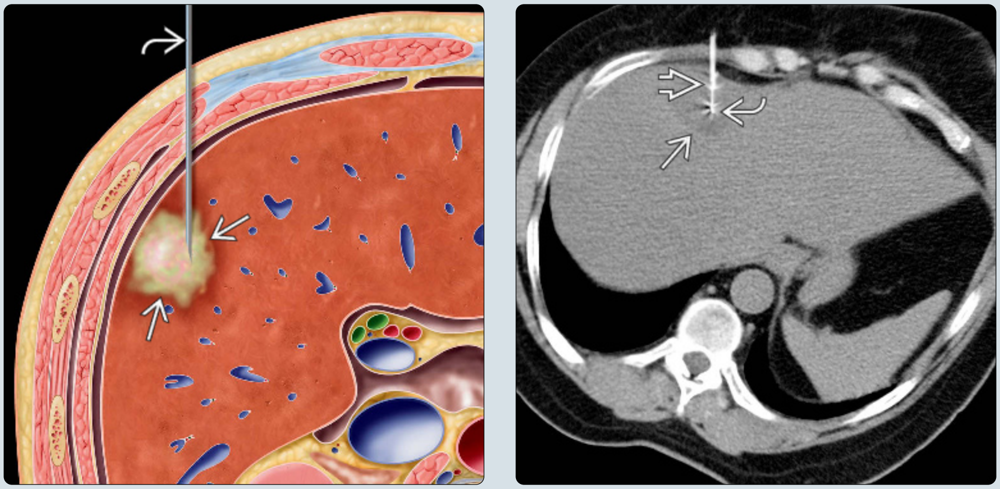
- Indications
    - Diagnose, stage, &/or grade diffuse parenchymal disease
    - Evaluate lesion of unknown/indeterminant etiology
        - Pathology, microbiology, cytology
    - Grading &/or staging of known malignancy

PROCEDURE

- Shortest route that avoids intervening structures
- Fine-needle aspiration &/or core biopsy
    - Increased diagnostic yield if both obtained
- Coaxial-needle technique minimizes number of passes through overlying tissues
- **US guidance**
    - Doppler imaging to assess for intervening vessels
    - Single-needle or coaxial-needle technique
- **CT guidance**
    - Perform preliminary scan with radiopaque grid
    - Usually coaxial-needle technique
- Discuss specimen preparation with cytology/pathology department prior to biopsy
- Biopsy of intraparenchymal lesion
    - Traverse intervening normal parenchyma to reduce hemorrhage risk
- Liver biopsy: Preprocedure paracentesis if ascites present
- Renal biopsy: Aim away from hilum into cortex

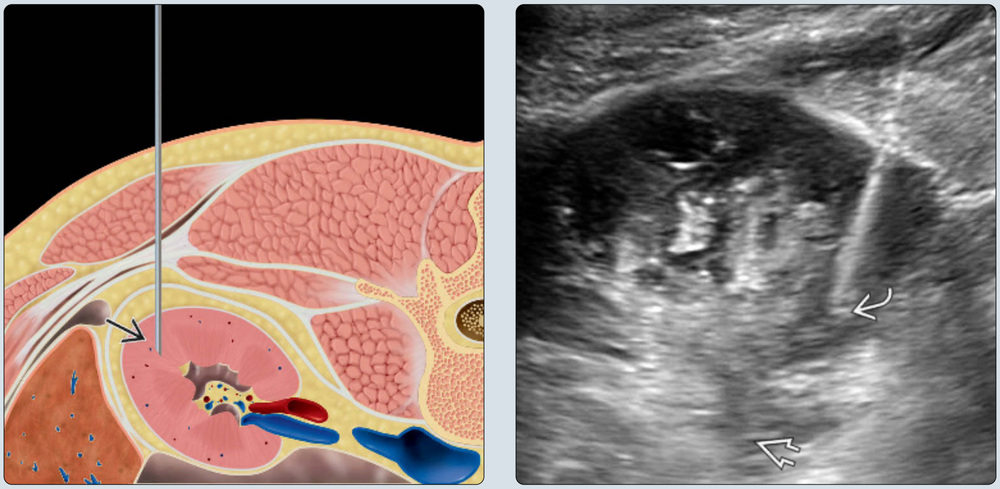
POST PROCEDURE

- Monitor for complications
    - Consider CT; low threshold appropriate to reimage
- Overall risk of significant hemorrhage < 1%


Percutaneous Focal Hepatic Biopsy

Percutaneous Focal Hepatic Biopsy

(Left) *Graphic demonstrates percutaneous introduction of a biopsy needle ↪ into a hepatic lesion →. This is an example of a focal biopsy of a well-defined lesion, for which a coaxial needle technique is typically used to obtain core biopsy specimen.* **(Right)** *Axial NECT demonstrates coaxial placement of a core biopsy needle ↪ into a low-attenuation hepatic lesion → through an 18-gauge introducer needle ⇨.*


Percutaneous Renal Biopsy

Percutaneous Renal Biopsy

(Left) *Graphic demonstrates percutaneous introduction of a biopsy needle → within the renal cortex. This is an example of a nonfocal biopsy of renal parenchyma, for which either single- or coaxial-needle technique can be used.* **(Right)** *US was obtained during percutaneous biopsy of a transplant kidney. Single-needle technique was used to obtain several core samples. 18-gauge needle can be seen with its tip in the renal cortex ↪. Simultaneous visualization of the renal hilum ⇨ helps prevent malposition of the biopsy needle.*

TERMINOLOGY

Definitions

- Biopsy: Tissue acquisition from organ/lesion using large-gauge needle for microbiologic &/or pathologic analysis
  - Nonfocal (random) biopsy: Biopsy of organ parenchyma to assess diffuse disease
  - Focal (targeted) biopsy: Biopsy of discrete lesion
- Fine-needle aspiration (FNA): Aspiration of cells from target lesion using small-gauge needle for cytologic analysis

PREPROCEDURE

Indications

- Diagnose, stage, &/or grade diffuse parenchymal disease
  - Liver (native and transplant)
  - Kidney (native and transplant)
- Evaluate lesion of unknown or indeterminant etiology
  - Pathology: Benign vs. malignant
  - Microbiology: Sterile vs. infected
  - Cytology
- Grading &/or staging of known malignancy

Contraindications

- Uncorrectable bleeding diathesis
- Lack of safe access
- Echinococcal cysts (risk of anaphylaxis)

Preprocedure Imaging

- Nonfocal biopsy: Preprocedure imaging not routinely performed
  - Evaluate for ascites in case of liver biopsy
- Focal biopsy: Must review preprocedure imaging
  - Exclude lesions with definite benign imaging features
  - Assess location of lesion and surrounding structures
  - Plan route to lesion
    - Safety of access (vessels, bowel, or viscera)
    - Consider location of tract and implication of potential seeding on future surgical management
  - Select modality for imaging guidance (US or CT)
    - **US**
      - No radiation, low cost, portable
      - Real-time anatomy/needle localization
      - Best for cases requiring transvaginal (TV) or transrectal (TR) access
      - Limited by body habitus, bone, and air/gas
      - Necessitates experience and eye-hand coordination
    - **CT**
      - Better resolution of target/intervening structures
      - Improved visualization in obese patients
      - Longer procedure times, expensive, radiation exposure
      - Not limited by air/gas, larger body habitus
      - Real-time visualization only with CT fluoroscopy

Getting Started

- Things to check
  - Pertinent clinical history and physical examination
    - Procedure indications
    - Current medications (anticoagulants/antiplatelet agents)
    - Allergies
  - Laboratory parameters
    - Complete blood count (CBC)
      - Platelets generally (not always) > 50,000/μL
    - Coagulation profile
      - International normalized ratio (INR) ≤ 1.5
      - Normal prothrombin time (PT), partial thromboplastin time (PTT)
    - Pregnancy test if using CT guidance
- Medications
  - Anesthesia
    - 1% lidocaine local anesthetic
    - Procedural sedation as necessary
      - Fentanyl, midazolam typically used
  - Prophylactic antibiotics
    - Liver/renal transplant biopsy
      - Confer with transplant team
    - Prostate biopsy
    - High suspicion of infected lesion at biopsy
- Equipment list
  - **General**
    - US equipment
      - 2- to 12-MHz transducer (location dependent)
      - Sterile ultrasound probe cover/gel
    - CT equipment
      - Radiopaque grid
    - Specimen collection
      - Glass slides
      - Saline preparation
      - Preservative preparation depending on other desired tests (formalin, alcohol, methanol, etc.)
  - **Single-needle technique**
    - 25-gauge needle for thyroid or superficial lymph node/nodule FNA
    - 20-gauge biopsy gun for thyroid or superficial lymph node/nodule core biopsy
    - 16- to 18-gauge core biopsy gun for nonfocal or nonsuperficial biopsy
  - **Coaxial-needle technique**
    - 14- to 19-gauge introducer needle
      - Must be large enough to accept biopsy device
    - 16- to 20-gauge core biopsy device
    - 22-gauge needle (e.g., Chiba, Franseen) for FNA

PROCEDURE

Patient Position/Location

- Best procedure approach
  - **General**
    - Shortest route that avoids intervening structures
  - **Nonfocal kidney biopsy**
    - Prone for native kidney
      - Lateral decubitus if unable to lie prone
    - Supine for transplant kidney
  - **Nonfocal liver biopsy**
    - Supine or left posterior oblique
  - **Focal biopsy**
    - Position depends on lesion location
    - Special approaches
      - Transgluteal (TG): Decubitus or prone

      - TV: Dorsal lithotomy
      - TR: Left lateral decubitus

Equipment Preparation

- Be familiar with operation of core biopsy gun as devices vary in operation
  - Usually automated, spring-activated cutting system
  - Consider length of "throw" (often adjustable)

Procedure Steps

- **General**
  - Review preliminary images
    - Verify chosen modality adequately displays target
    - Identify safe route to target
  - To increase diagnostic yield
    - Target periphery of necrotic lesions
    - Use different trajectory for biopsies with multiple passes
    - Utilize onsite cytopathologists to evaluate adequacy of sample at time of biopsy
    - Obtain both core biopsy and FNA when possible
- **US-guided procedures**
  - Image target in real time prior to preparing site
    - Select skin entry site and mark skin
    - Doppler imaging to assess for intervening vessels
  - Place sterile cover on transducer
  - Sterilely prepare and drape skin
  - Reimage target in real time
  - Administer 1% lidocaine local anesthetic
  - Skin nick with #11 scalpel blade for larger needles
  - Advance needle to target under real-time guidance
- **CT-guided procedures**
  - Place radiopaque grid on skin
  - Obtain preliminary CT images
  - Select skin entry site and mark on grid
  - Sterilely prepare and drape skin
  - Administer 1% lidocaine local anesthetic
  - Skin nick with #11 scalpel blade for larger needles
  - Advance needle to target
    - Obtain CT after each needle adjustment
    - Remove stylet to reduce streak artifact that may obscure lesion or needle tip
  - If focal biopsy of isodense lesion is to be performed
    - Review preprocedure images and advance needle to target based on anatomic landmarks
    - Obtain intravenous contrast-enhanced scan if needed
- **Biopsy techniques**
  - **Single-needle technique**
    - Appropriate for US-guided biopsies
      - Kidney/liver parenchyma
      - Thyroid nodules
      - Superficial lymph nodes/nodules/masses
    - Advance needle to target under real-time visualization
      - Use core biopsy gun for nonfocal biopsy
      - FNA or core biopsy for thyroid or superficial lesion
  - **Coaxial-needle technique**
    - Appropriate for US- or CT-guided biopsies
      - Focal & nonfocal biopsies
    - Cumbersome for very superficial lesions
    - Minimizes number of passes through overlying tissues
      - Once introducer needle in place, may obtain multiple samples with FNA and core needle
    - Allows tract embolization for active bleed/potential bleed risk
      - Postbiopsy blood patch, Gelfoam torpedo/slurry delivery
    - Advance coaxial introducer to target
      - Remove stylet
      - Ensure introducer needle is of appropriate size to receive desired core or FNA needle
    - Advance coring or FNA needle into lesion via introducer
      - US: Real-time visualization
      - CT: Real-time CT-fluoro, or intermittent step imaging while advancing needle tip to lesion
  - **FNA technique**
    - Advance needle to target periphery under real-time US guidance
    - Move needle in and out of target with to-and-fro motion
      - Use real-time US guidance to avoid passing through lesion and damaging regional structures
    - Remove needle and aspirate contents
      - If no on-site cytopathologist, follow specimen preparation per guidelines of pathology department
    - In case of poor aspirate volume
      - Attach 3-5 mL syringe to FNA needle (or via connector tubing)
      - Reinsert needle and repeat to-and-fro motion while applying suction
      - Release suction prior to removing needle to prevent aspiration of blood
  - **Core biopsy technique**
    - Be comfortable with operation of selected core biopsy device
      - Do not fire unfamiliar equipment 1st time in patient; dry-fire on prep table
    - Advance biopsy device until needle tip at desired location
      - Position at periphery of lesion such that "throw" of device will end within lesion and not beyond
      - "Throw" length is adjustable on many devices
    - Activate (fire) biopsy device
      - Record US image to demonstrate device position
    - Remove biopsy device
      - If no on-site cytopathologist, follow specimen preparation per guidelines of cytology/pathology department
    - Repeat process to obtain multiple samples
- **Specific considerations by location**
  - **Adnexa**
    - Preprocedure consultation with gynecologic oncology
      - Assess theoretical risk of intraperitoneal spread of disease
      - Highly suspicious lesions may proceed directly to surgery to reduce risk of seeding
    - Transabdominal (TA) approach if possible
    - TG approach if TA not possible
      - Choose route as close to sacrococcygeal margin as possible to avoid neurovascular structures

- TV approach (continued)
    - Infiripiriformis approach may be less painful
  - TV approach if necessary
    - Preprocedure TV US to demonstrate adequate visualization lesion
    - Wash vaginal vault with preparatory solution
    - Visualize target with TV US and perform Doppler to assess for intervening vessels
    - Activate needle guide markers on US display
    - Advance needle along needle guide into lesion
- **Adrenal**
  - Lateral decubitus position, ipsilateral side down
    - Reduces diaphragmatic excursion
  - Consider pheochromocytoma: Evaluate with preprocedure labs
  - If high suspicion of pheochromocytoma
    - Preprocedure medication to control blood pressure
    - Consider assistance of anesthesiology for monitoring and management
- **Kidney**
  - Nonfocal biopsy: Target renal cortex to obtain glomeruli
    - Needle trajectory pointed away from hilum
    - Native: Lower pole generally preferred
    - Transplant: Upper pole generally preferred
    - 16- to 18-gauge core: Single or coaxial technique
  - Focal biopsy: Target lesion via path providing intervening normal renal parenchyma
    - Allows for tamponade effect between lesion and capsule to reduce hemorrhage
  - CT guidance if kidney deep, large body habitus, poor visualization on US
    - Prone or lateral decubitus (ipsilateral side down)
    - Reduces diaphragmatic excursion, with reduced motion of kidney and avoidance of lung
- **Liver**
  - Nonfocal biopsy: Subcostal or subxiphoid approach over intercostal approach when possible
    - Reduces pain
    - Lessens risk of pneumothorax and hemothorax
  - Focal biopsy: Target lesion via path providing intervening normal hepatic parenchyma
    - Allows for tamponade effect between lesion and capsule to reduce hemorrhage
  - US often visualize dome lesions; provide path avoiding pleura
  - CT guidance if poor visualization on US
    - Angle gantry for optimal visualization of pleura/lung
    - Transpleural approach may be unavoidable in case of diaphragmatic lesions
  - Consider preprocedure paracentesis in setting of ascites
    - Shortens path to prevent target displacement
    - Improves tamponade effect to reduce hemorrhage
    - Lessens risk of peritonitis if lesion infected
  - 16- to 18-gauge: Single- or coaxial-needle technique
- **Pancreas**
  - Endoscopic biopsy typically preferred
  - Occasionally, CT-/US-guided biopsy required
    - US visualization may displace intervening bowel
    - Avoid dilated pancreatic duct
    - Risk of postprocedure pancreatitis as with ERCP
- **Peritoneum or mesenteric lymph nodes**
  - Associated with significant movement of target
    - Biopsy may be like "bobbing for apples"
  - Dual-needle technique
    - Introducer needle placed alongside target to reduce motion
    - 2nd 19-gauge introducer/20-gauge core biopsy system advanced into target to obtain biopsy
  - Transenteric/transcolonic approach may be necessary
- **Prostate**
  - TR US-guided approach preferred
    - Target peripheral zone
  - Antibiotic prophylaxis
    - Ciprofloxacin PO x 3 days starting day before biopsy
    - Gentamicin IM x 1 immediately prior to procedure
  - 20-gauge core biopsy gun
  - 12 core samples for Gleason scoring
    - 2 core samples from base, mid, and apex on each side of prostate
    - 1 sample from each side may be from central gland
  - Caution patient
    - Postprocedure hematuria, hematochezia, hematospermia
    - Abstain from sex for 1 week
- **Spleen**
  - 2-10 x risk of hemorrhage compared to liver biopsy
    - Consider prior surgical consultation if endovascular embolization will be unavailable at time of biopsy
  - CT guidance recommended
    - More sensitive for postprocedure hemorrhage
  - Coaxial technique preferred
    - Smaller gauge needle may reduce risk of hemorrhage
    - e.g., 19-gauge introducer + 20-gauge biopsy gun
- **Thyroid**
  - Obtain 4-6 FNA specimens with 25-gauge needle
  - Core biopsy not required unless specified or prior FNA nondiagnostic
    - 20-gauge core biopsy usually sufficient

Findings and Reporting

- Imaging
  - Preprocedure: Description of focal lesion
  - Intraprocedure: Identify needle trajectory/tip position
  - Postprocedure: Evaluation for immediate complications
- Procedure
  - Technique
    - Imaging modality, single vs. coaxial, gauge
  - Samples obtained
    - Core vs. FNA
    - Number of passes
  - Immediate complications and response
- Samples
  - Preparations (slides, saline, formalin, etc.)
  - Tests ordered
- Postprocedure recommendations and follow-up

Alternative Procedures/Therapies

- Radiologic
  - Transjugular liver/renal biopsy
- Surgical
  - Open or laparoscopic biopsy
- Other
  - Endoscopic US-guided FNA
  - Transbronchial core biopsy or FNA

POST PROCEDURE

Things to Do

- Postprocedure hemodynamic and oxygen monitoring
  - Tachycardia &/or hypotension
    - Hemorrhage
  - Hypoxemia, dyspnea, &/or chest pain
    - Pneumothorax
  - Hypertension after renal/adrenal biopsy
    - Page kidney due to compression of renal parenchyma by subcapsular collection
    - Adrenal crisis in case of pheochromocytoma

Things to Avoid

- Nontarget sampling
  - Mobile lesion
  - Inappropriate length of "throw" of biopsy gun
- Traversal of regional structures
  - Large vessels
  - Dilated biliary or pancreatic ducts
  - Lung/pleura during intraabdominal biopsy
    - Transpleural route may be necessary in some cases

OUTCOMES

Problems

- Nondiagnostic biopsy
  - May repeat biopsy with on-site cytopathology or frozen section confirmation before needle removal
  - Obtain both FNA and core specimen if focal lesion
  - Alter modality
    - CT guidance if US previously used
- Hemorrhage
  - Most common after liver, kidney, and splenic biopsy
    - Indications for tract embolization with Gelfoam
      - Intraprocedural images demonstrating hematoma
      - Significant back bleeding via introducer needle
      - Uncorrected bleeding diathesis
      - Routinely after splenic biopsy
    - Risk of serious hemorrhage typically < 1%
  - Postprocedure monitoring
    - Frequent assessment of vital signs
    - Extended or overnight observation for hepatic or native renal biopsy
    - Delayed postprocedure imaging
  - Uncontrolled or hemodynamically significant bleeding
    - Obtain large bore IV access for fluid resuscitation
    - Type and cross for blood products
    - Definitive management
      - Angiography with endovascular embolization
      - Surgical consultation
- Pain
  - Mild: Conservative management
  - Severe: Evaluate for complication (hemorrhage)

Complications

- Most feared complication(s)
  - Hemodynamically significant hemorrhage
- Immediate/periprocedural complication(s)
  - Pain, hemorrhage, vasovagal reaction, pneumo/hemothorax
- Delayed complication(s)
  - Pseudoaneurysm, sepsis, pancreatitis, Page kidney
- Other complications
  - Hemoptysis, ureteral obstruction

Expected Outcomes

- Diagnostic yield depends on
  - Biopsy target (size, location)
  - Technique
  - Presence of on-site cytopathology
- Reported diagnostic accuracy of focal lesion biopsy
  - Liver: 83-95%
  - Kidney: 77-89%
  - Pancreas: 89%
  - Other sites: 70-90%
- False-negative results > > false-positive results

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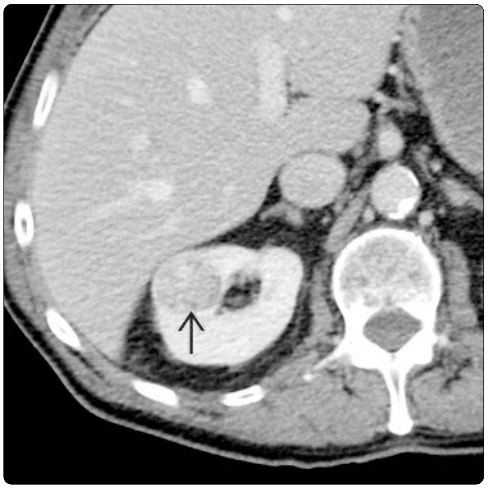
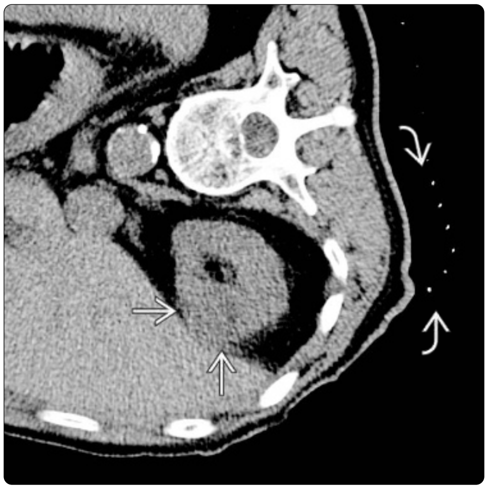
CT-Guided Focal Renal Biopsy: Preprocedure Scan

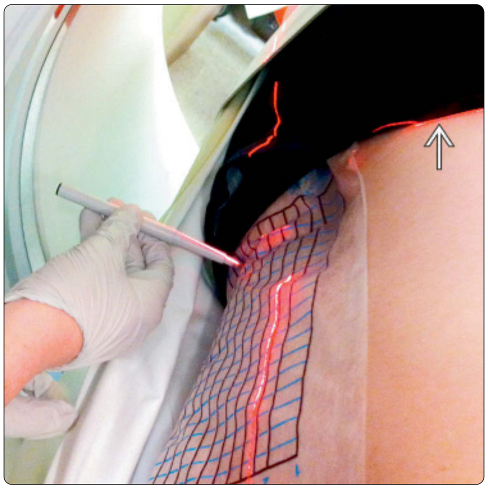


CT-Guided Focal Renal Biopsy: Preprocedure Scan

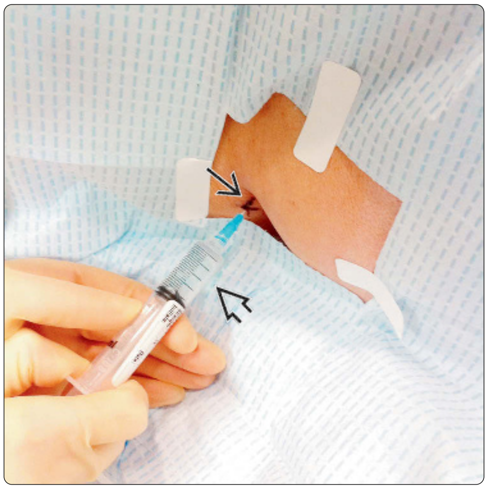


(Left) *Axial CECT demonstrates a solitary solid renal mass ⇨ in the anterolateral right kidney.* **(Right)** *Axial NECT obtained in preparation for CT-guided biopsy of the focal renal mass ➡ shows a grid with radiopaque lines ⤴ posteriorly on the overlying skin. Patient is in right lateral decubitus position to limit diaphragmatic excursion, reducing kidney movement, and preventing lung parenchyma from entering biopsy path.*

CT-Guided Focal Renal Biopsy: Localizing With Radiopaque Grid

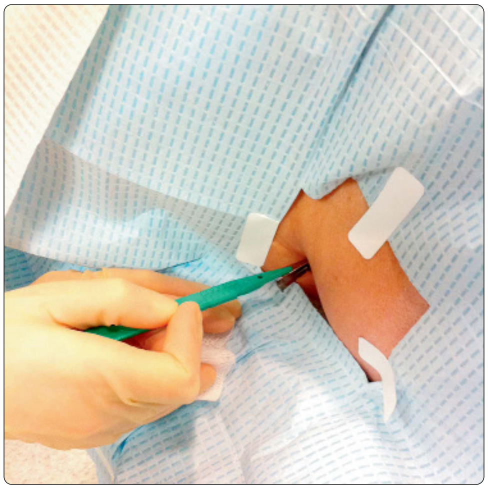


CT-Guided Focal Renal Biopsy: Local Anesthetic Administration

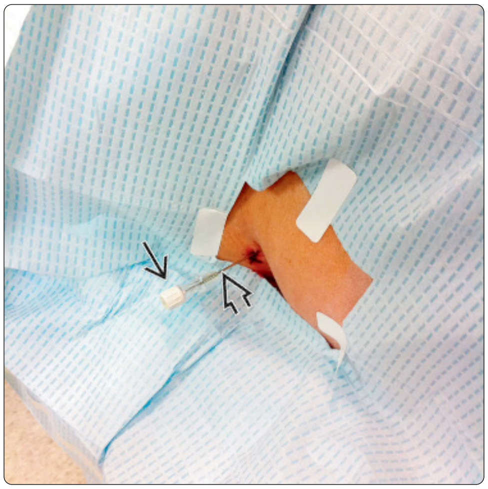


(Left) *Photograph shows the localizing grid used to select the point for placing the introducer needle based on preliminary CT images, which is then marked by a pen. The axial red laser line ➡ demarcates the slice position corresponding to the CT image from which the skin entry site was selected.* **(Right)** *After the skin has been sterilely cleansed and the sterile field has been draped, 1% lidocaine local anesthetic ⇨ is administered at the marked skin access point ⇨.*

CT-Guided Focal Renal Biopsy: Skin Nick



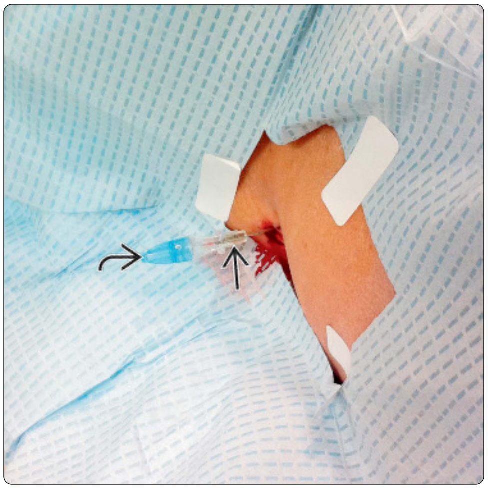
CT-Guided Focal Renal Biopsy: Introducer Needle



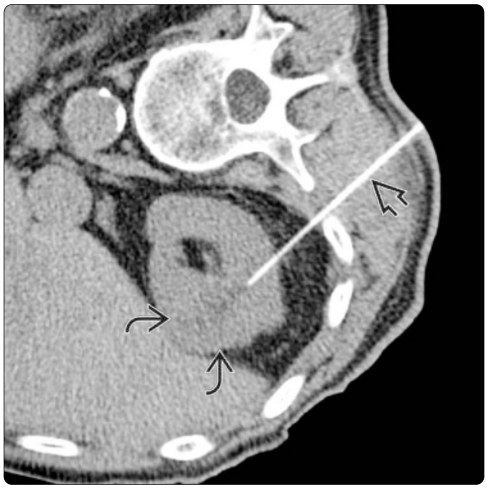
(Left) *A skin nick is made using a #11 scalpel to facilitate insertion of a 17-gauge introducer needle.* **(Right)** *17-gauge introducer needle ⇨ with an inner stylet ⇨ is inserted percutaneously via skin nick. Angle and depth of insertion is determined by the preliminary CT scan. The needle tip position within the renal parenchyma may often be inferred by observing the needle oscillating in the craniocaudal axis with respiration.*

(Left) *In order to assess the tip position after placement of the introducer needle →, the inner stylet is removed (so as to reduce streak artifact) and a cap ↪ is placed on the needle hub prior to CT scan.* **(Right)** *Axial NECT shows introducer needle ⇨ in the right kidney with its tip at the periphery of the target lesion ↪. Stylet was removed prior to scan to reduce streak artifact.*

CT-Guided Focal Renal Biopsy: Removal of Stylet

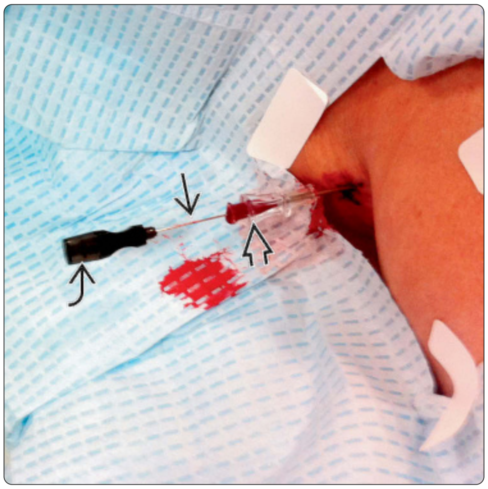


CT-Guided Focal Renal Biopsy: Introducer

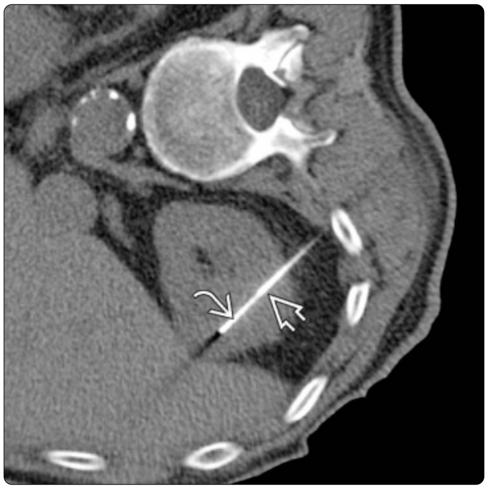


(Left) *22-gauge Chiba needle → is inserted through the hub ⇨ of the introducer needle to be used for fine needle aspirate (FNA). The inner stylet ↪ of the Chiba needle is left in place during CT scan to limit blood products from filling the barrel of the needle.* **(Right)** *Axial NECT shows the Chiba needle ⤻ has entered coaxially via the introducer needle ➡ with its tip located in the target lesion, as desired to obtain an FNA sample. The introducer tip remains at the periphery of the lesion.*

CT-Guided Focal Renal Biopsy: Coaxial Technique

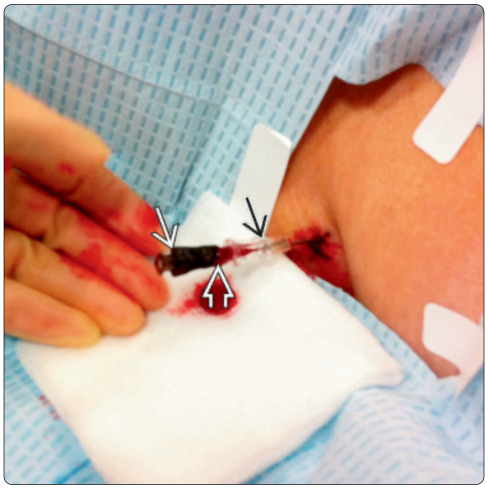


CT-Guided Focal Renal Biopsy: Coaxial Technique

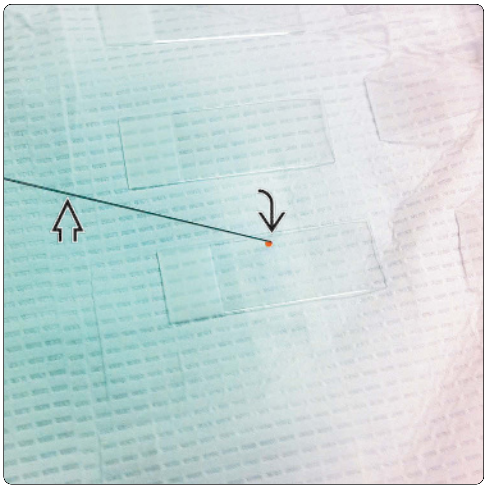


(Left) *Inner stylet is removed from the Chiba needle hub ➜. The needle ➡ is then moved back and forth into the lesion via to-and-fro motion. A 10 mL syringe may be attached to the Chiba needle to provide suction, if needed. The introducer needle → remains stationary.* **(Right)** *The FNA needle ⇨ is removed, and the stylet is replaced into the introducer needle (not shown). If on-site cytopathology is unavailable, the specimen preparation begins by placing the aspirate ↪ onto a glass slide.*

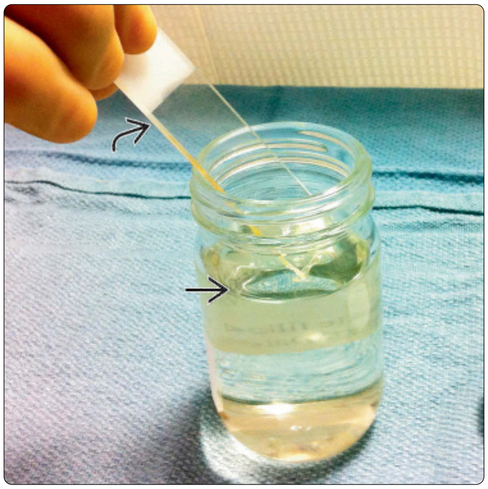
CT-Guided Focal Renal Biopsy: FNA via Coaxial Technique



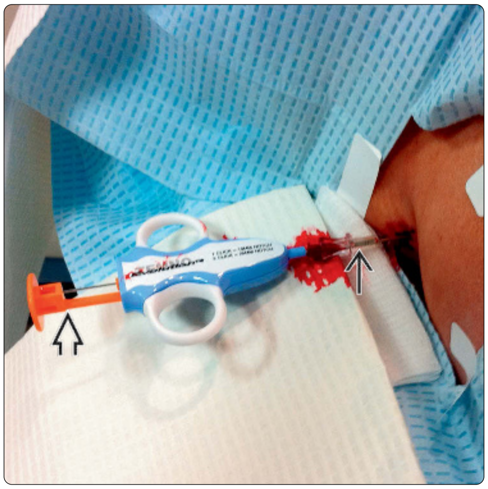
CT-Guided Focal Renal Biopsy: FNA Specimen Preparation



CT-Guided Focal Renal Biopsy: FNA Specimen Preparation

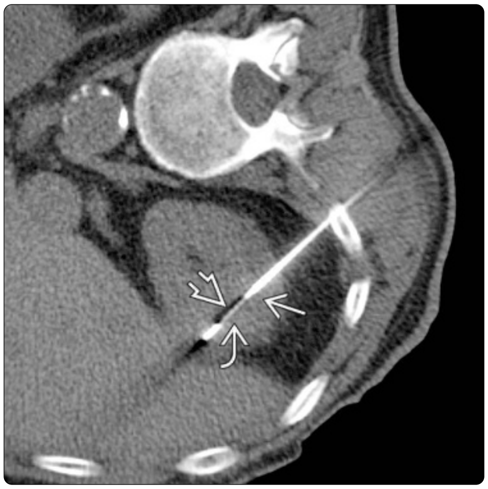


CT-Guided Focal Renal Biopsy: Core Biopsy Needle Insertion

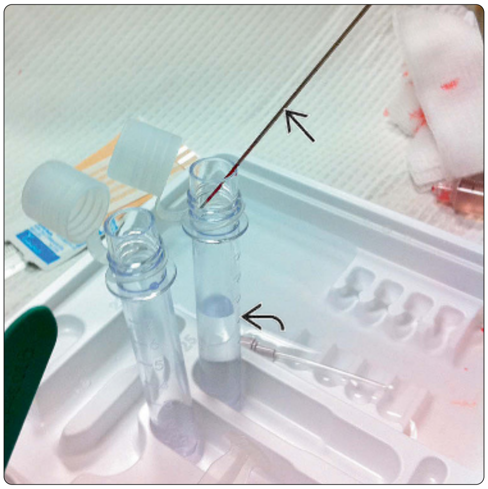


(Left) *After aspirate is appropriately prepared on slides* ↪*, they are inserted into a container filled with 95% ethanol* ⇨ *for tissue fixation. Preparation of the slides should be performed expeditiously in order to prevent air drying of the FNA specimen.* **(Right)** *After removal of the introducer stylet, an 18-gauge core biopsy gun is advanced through the same introducer needle* → *used for FNA. The cutting portion of the biopsy needle is advanced into the lesion by depressing the plunger* ⇨ *of the biopsy gun.*

CT-Guided Focal Renal Biopsy: Core Biopsy Needle

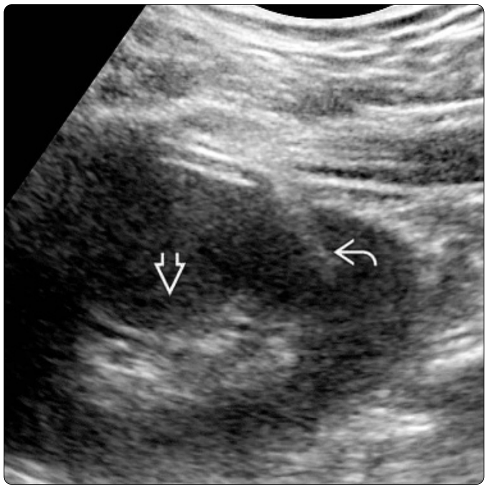


CT-Guided Focal Renal Biopsy: Core Biopsy Specimen Preparation

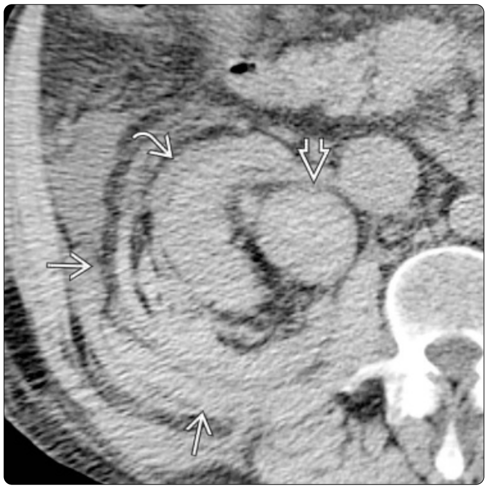


(Left) *Axial NECT shows the cutting portion of the biopsy needle (notch)* ⇨ *beyond the tip of the introducer* → *within the target lesion* ↪*. The plunger of the biopsy gun is depressed further until a "click" is heard, indicating firing of the device.* **(Right)** *After the core biopsy gun has been removed and the stylet has been replaced into the introducer needle, the specimen is extruded from the core biopsy needle* → *into a specimen container* ↪ *of normal saline or formalin, per pathology requirements.*

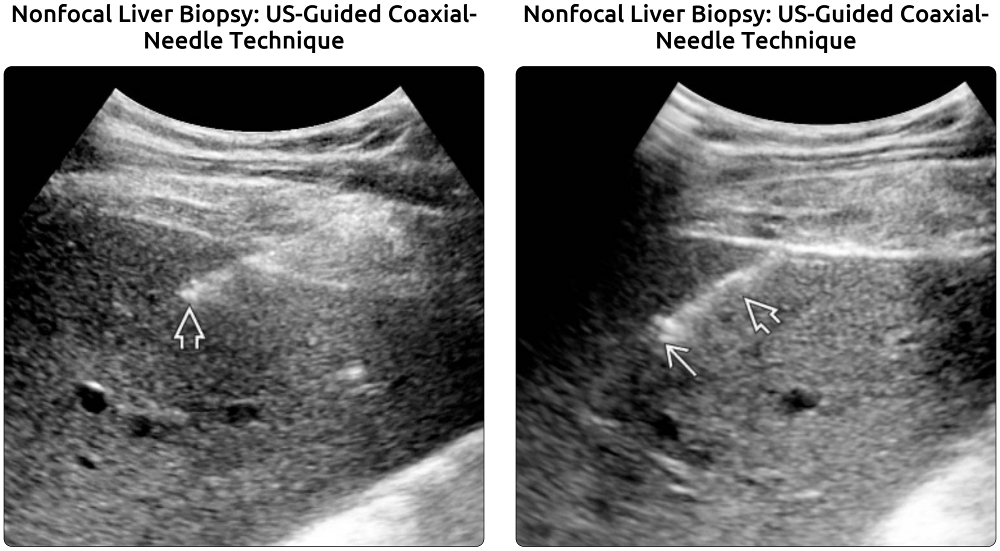
Nonfocal Renal Biopsy: US-Guided Single-Needle Technique



Nonfocal Renal Biopsy: Complication



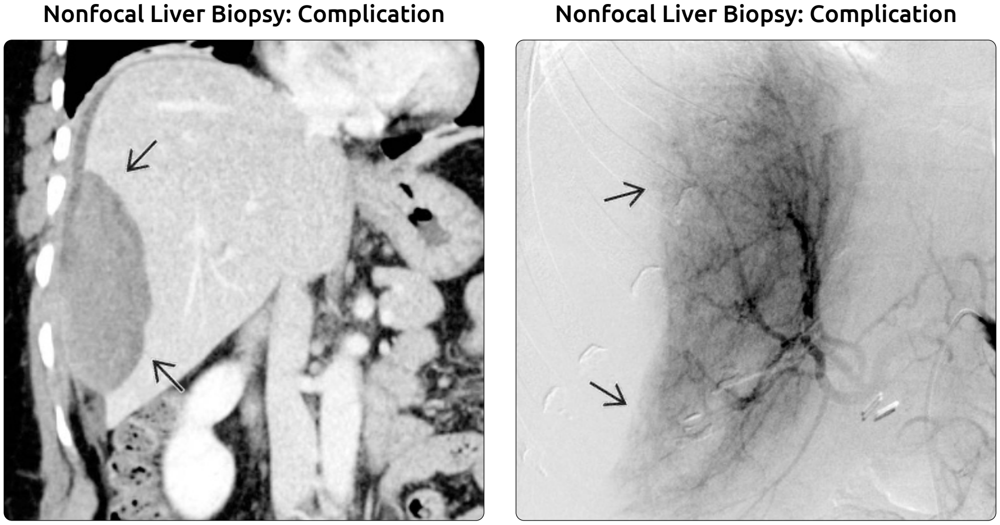
(Left) *Sagittal US of left kidney shows a core biopsy needle* ↪ *has been percutaneously introduced into the cortex of the lower renal pole under real-time guidance. The needle trajectory is directed away from the renal hilum* ⇨ *to reduce the risk of complication.* **(Right)** *Axial NECT in a patient with right flank pain and hematuria several hours after an US-guided nonfocal biopsy of the right kidney* ↪ *is shown. Hemorrhage distends the pararenal space* → *as well as into the renal pelvis* ⇨*.*



Nonfocal Liver Biopsy: US-Guided Coaxial-Needle Technique

Nonfocal Liver Biopsy: US-Guided Coaxial-Needle Technique

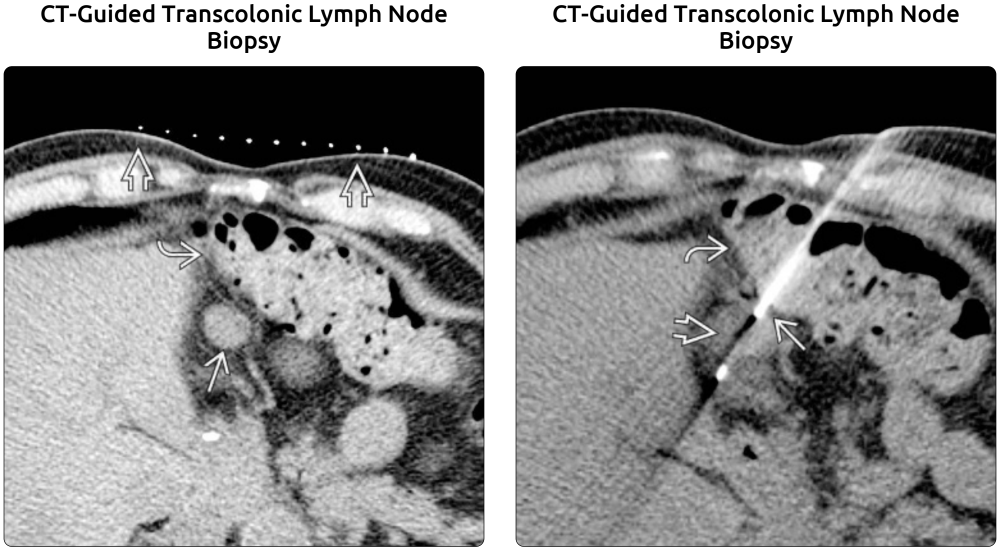
(Left) *Transverse US of the liver, obtained through an intercostal approach, shows percutaneous advancement of a 17-gauge introducer needle with tip* ➡ *in the periphery of the liver in preparation for a nonfocal biopsy.* **(Right)** *Through the introducer needle* ➡*, an 18-gauge core biopsy needle is advanced under real-time guidance until its tip is visualized in the liver parenchyma* ➡*. Using this coaxial technique facilitates the acquisition of multiple specimens through a single puncture of the liver capsule, reducing hemorrhage risk.*



Nonfocal Liver Biopsy: Complication

Nonfocal Liver Biopsy: Complication

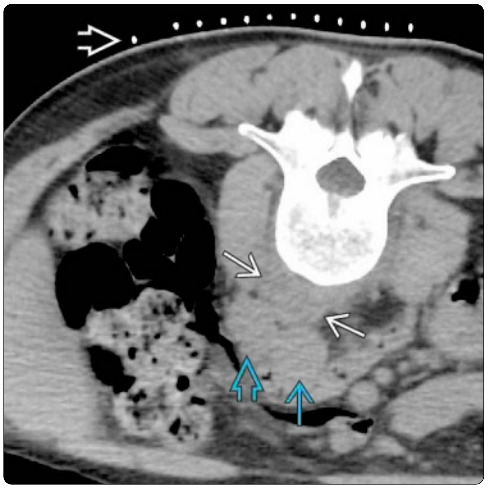
(Left) *Coronal CECT in a 52-year-old woman with right upper quadrant pain shows a large subcapsular hematoma* ⇨*. The patient had undergone US-guided liver biopsy 3 days prior.* **(Right)** *Hepatic DSA was subsequently obtained for further evaluation. No contrast extravasation is noted, although mass effect by the subcapsular hematoma* ⇨ *is seen. Gelfoam embolization of the right hepatic artery was prophylactically performed based upon location of biopsy.*



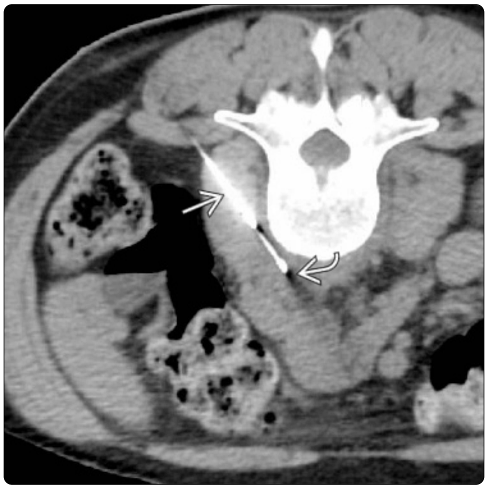
CT-Guided Transcolonic Lymph Node Biopsy

CT-Guided Transcolonic Lymph Node Biopsy

(Left) *Preliminary NECT was performed in a patient with small cell carcinoma to localize a PET-avid gastrohepatic lymph node* ➡ *for biopsy. Note the transverse colon* ↪ *overlies the lesion anteriorly. A grid* ➡ *has been placed on skin to determine point of access.* **(Right)** *As an alternative access path could not be found, a 19-gauge introducer needle* ➡ *was advanced through the colon* ↪ *into the lymph node. The notch* ➡ *of a coaxially introduced 20-gauge core biopsy gun is well-seated within the lymph node.*

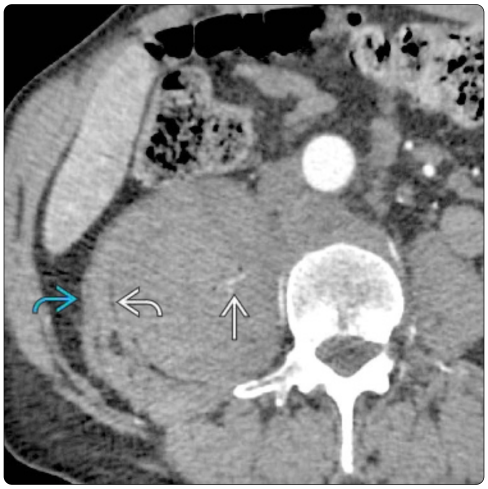


Percutaneous Retroperitoneal Mass Biopsy: Preprocedure Imaging

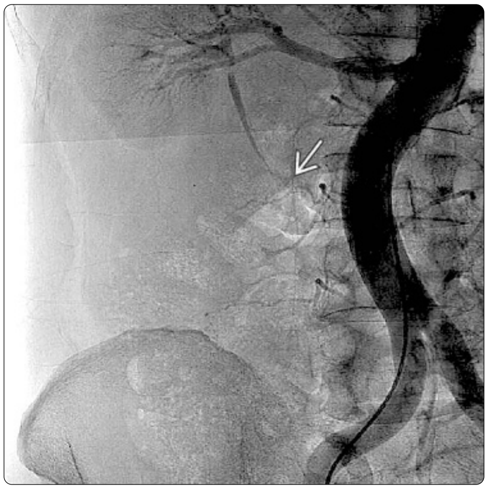


Percutaneous Retroperitoneal Mass Biopsy: Coaxial Biopsy

(Left) *Prone NECT obtained prior to procedure demonstrates a right paraspinal mass →, which had enlarged on multiple scans, precipitating request for biopsy. Close proximity to aorta → and IVC ⇨ is noted. A radiopaque grid ⇨ on the overlying skin helps guide the access site.* **(Right)** *An 18-gauge needle was advanced via coaxial technique through a 17-gauge introducer → to the periphery of the mass. A short biopsy "throw" is necessary to prevent the needle tip ↪ from extending through the mass.*

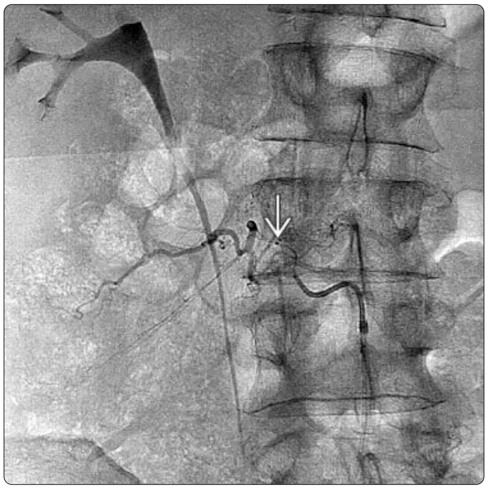


Percutaneous Retroperitoneal Mass Biopsy: Postprocedure CTA

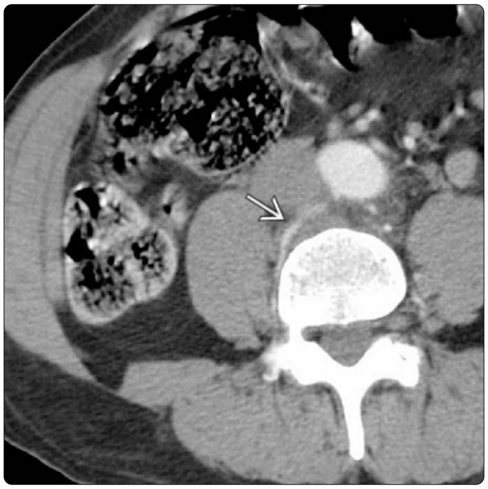


Percutaneous Retroperitoneal Mass Biopsy: Postprocedure Aortogram

(Left) *Due to significant immediate back bleeding through the introducer, the patient was placed in supine position and a CTA was performed. A large biopsy-related retroperitoneal hematoma ↪ with active contrast extravasation → displaces the psoas muscle ↪ laterally.* **(Right)** *The patient was brought to IR and an angiogram performed. The initial aortogram shows blush suspicious for active bleeding at the level of L3 →.*



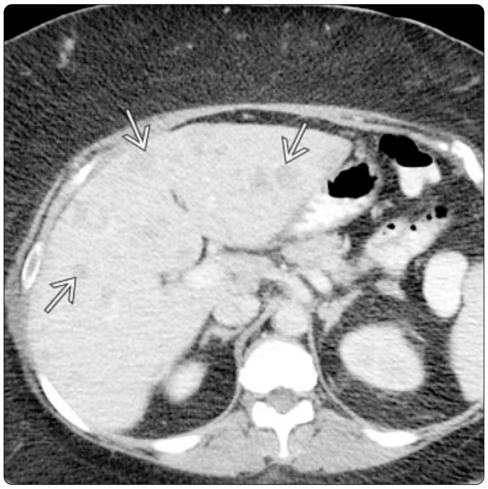
Percutaneous Retroperitoneal Mass Biopsy: Postprocedure Selective Arteriogram



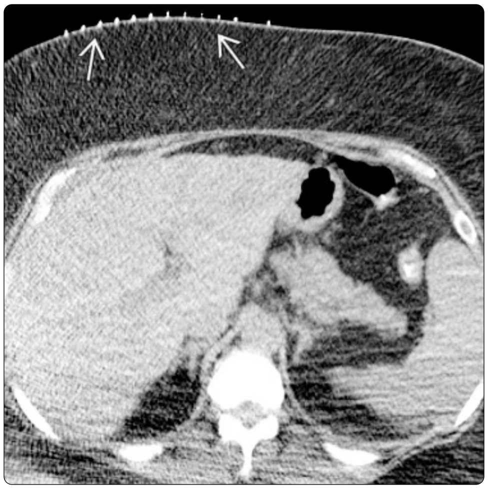
Percutaneous Retroperitoneal Mass Biopsy: Review of Prior Imaging

(Left) *Right L3 lumbar artery was selected with a microcatheter →. Although subsequent arteriogram did not reveal any definite active bleeding, selective embolization via Gelfoam was performed. The patient recovered completely without additional evidence of bleeding.* **(Right)** *Retrospective review of CECT from a year prior to biopsy shows the right L3 lumbar artery → in the area where the mass later developed. Although IVC and aorta were avoided during the biopsy, this artery was likely perforated.*

CT-Guided Focal Liver Biopsy: Preprocedure Scan

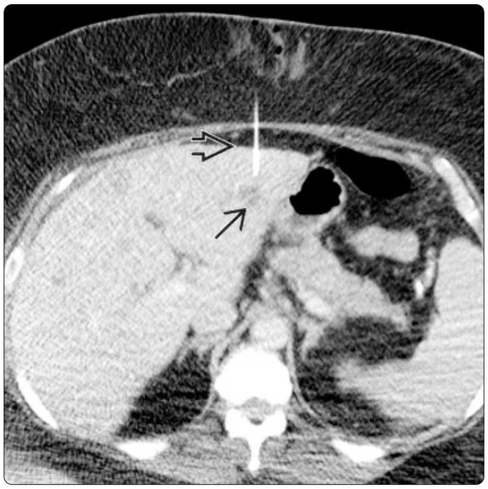


CT-Guided Focal Liver Biopsy: Grid Localization

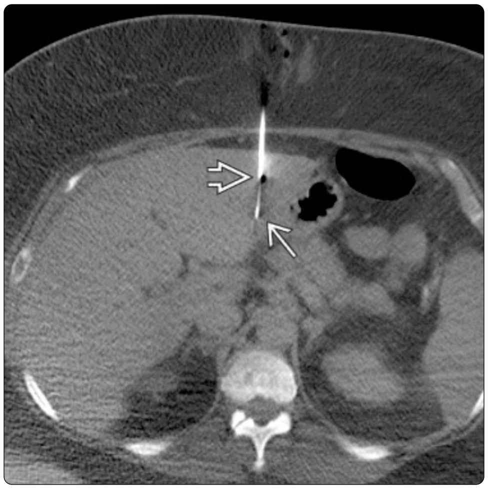


(Left) *Axial CECT demonstrates multiple hypodense lesions → scattered diffusely throughout the liver, most likely due to hepatic metastatic disease.* **(Right)** *Localizing axial NECT obtained in preparation for a CT-guided focal liver biopsy shows a grid with radiopaque lines → has been placed anteriorly on skin overlying the intended target lesion. Note that the liver lesions are poorly delineated on this noncontrast examination.*

CT-Guided Focal Liver Biopsy: Needle Placement

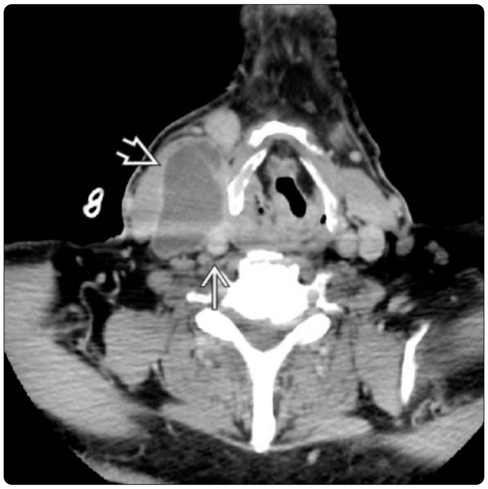


CT-Guided Focal Liver Biopsy: Core Biopsy

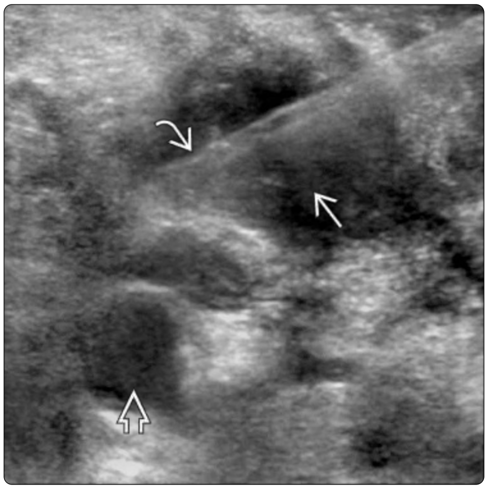


(Left) *Anatomic landmarks were used to guide percutaneous advancement of a 17-gauge introducer needle ⇨ via access point determined by grid. A contrast-enhanced scan was then performed to evaluate needle trajectory with respect to the target lesion →. In this case, the needle is appropriately directed toward the lesion.* **(Right)** *Coaxial technique is used to advance the needle of an 18-gauge core biopsy gun until the notch → is within the lesion. The introducer tip remains at the lesion periphery ⇨.*

Percutaneous Lymph Node Biopsy: Preprocedure Scan

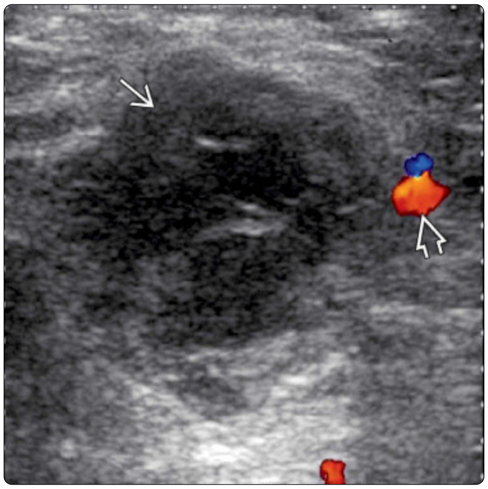


Percutaneous Lymph Node Biopsy: Coaxial Technique

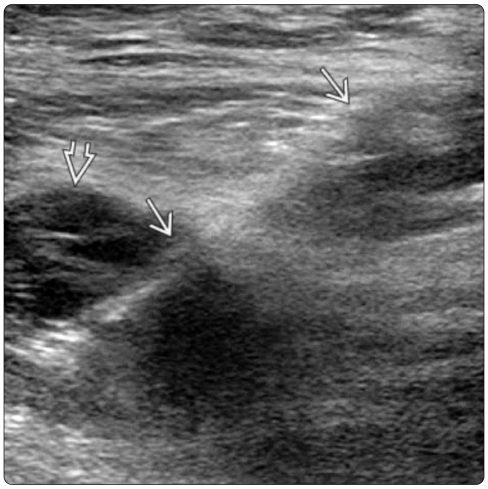


(Left) *Axial CECT in a 79-year-old man presenting with right neck swelling shows a soft tissue mass within the right piriform sinus. An enlarged, necrotic level III lymph node ⇨ was selected for US-guided biopsy. Note its close relationship with the right common carotid artery →.* **(Right)** *US clearly shows the necrotic lymph node. To increase biopsy yield, the 18-gauge needle is advanced through the periphery of the node, avoiding the necrotic center →. The needle tip ↪ is directed away from carotid artery ⇨.*

US-Guided Lymph Node Biopsy (Color Doppler)

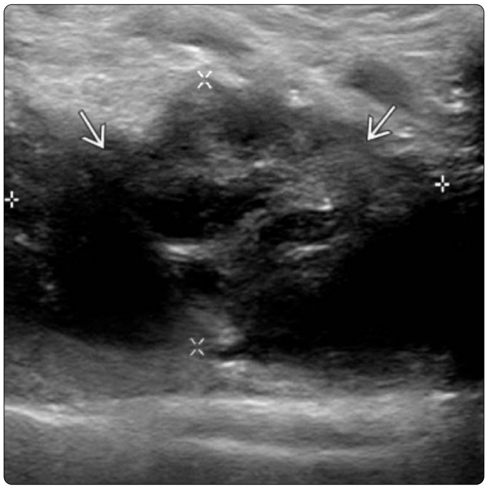


US-Guided Lymph Node Biopsy: Coaxial Technique

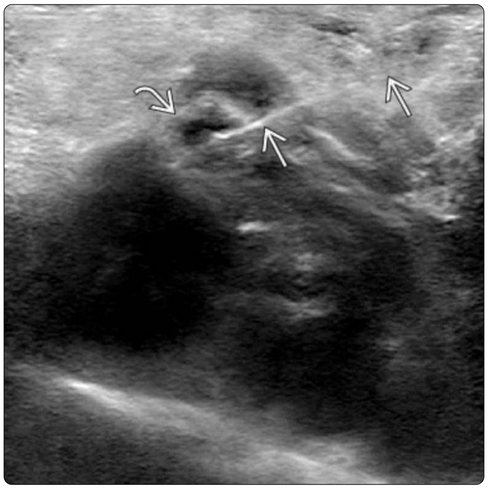


(Left) *A 61-year-old man with a history of metastatic lung cancer presented with palpable axillary lymph node ➡. US evaluation was performed for biopsy planning. Color Doppler imaging was used to identify an access path to avoid regional vessels ⇨.* **(Right)** *An 18-gauge biopsy device ➡ was advanced via coaxial technique through an introducer into the lymph node ⇨ under real-time US guidance. Care was taken to avoid the vessels seen on color Doppler images. Several core biopsy samples were obtained without complication.*

Percutaneous Lymph Node Biopsy: Preprocedure Imaging

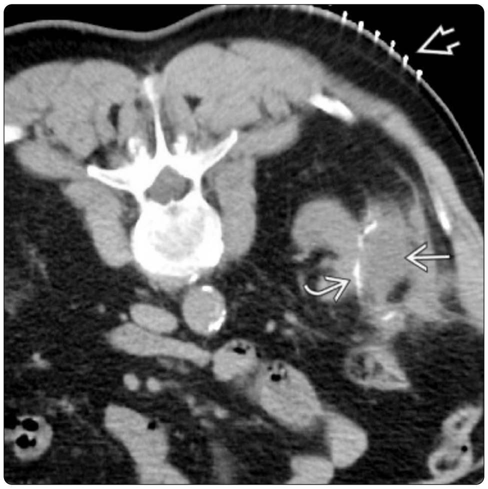


Percutaneous Lymph Node Biopsy: FNA

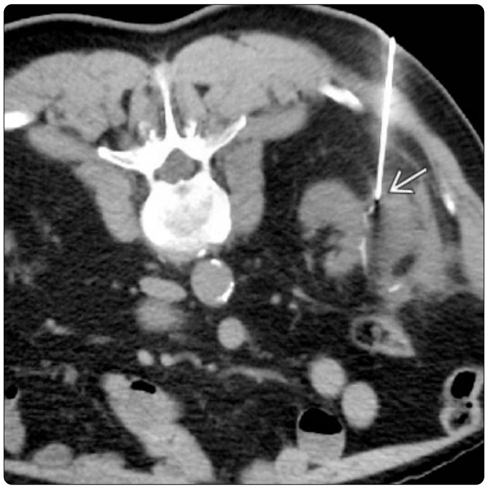


(Left) *A 54-year-old woman with a history of breast cancer presented with a palpable supraclavicular lymph node, which was found to be PET avid. Preprocedure US demonstrates a heterogeneous, enlarged superficial lymph node ➡.* **(Right)** *A 22-gauge needle ➡ was advanced under real-time US guidance into the hyperechoic component of the enlarged lymph node ↪. To-and-fro motion of the needle was performed during aspiration. On site cytopathology confirmed adequacy of the sample.*

Perirenal Mass Biopsy: Preprocedure Scan



Perirenal Mass Biopsy: Needle Placement



(Left) *An 81-year-old man status post partial nephrectomy to treat renal cell carcinoma presented with a mass ➡ measuring 10-50 HU adjacent to the suture line ↪. This broadened the differential to include recurrent mass vs. abscess. A radiopaque grid ⇨ was placed on the overlying skin to guide access.* **(Right)** *An 18-gauge introducer ➡ was placed in the area of interest. Coaxial biopsy attempt failed to produce tissue. Subsequent aspiration through the introducer produced purulent content, confirming abscess.*

Drainage Procedures

KEY FACTS

TERMINOLOGY

- **Aspiration**: Removal of fluid by needle or catheter
- **Drainage**: Fluid removal with catheter left indwelling
- **Seldinger technique**: Tracking drain into collection over wire which has been previously advanced into collection through hollow access needle
- **Trocar technique**: Advancing drain directly into collection over sharp inner stiffener

PREPROCEDURE

- **Indications**
    - Treatment of abscess
    - Fluid characterization
    - Alleviation of symptoms/fluid decompression

PROCEDURE

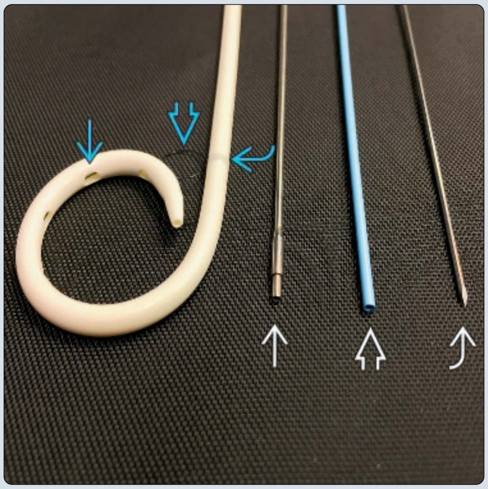
- **US guidance**
    - Doppler US to assess for intervening vessels
    - Direct trocar technique vs. Seldinger technique
- **CT guidance**
    - Perform preliminary scan with radiopaque grid
    - Tandem trocar technique vs. Seldinger technique
- **Transvaginal/transrectal approach**
    - Less frequent use; high catheter dislodgement rate
- **Transgluteal approach**
    - Stay close to sacrococcygeal margin
- **Postdrainage**
    - Irrigate with sterile normal saline
    - Consider gravity bag vs. suction

POST PROCEDURE

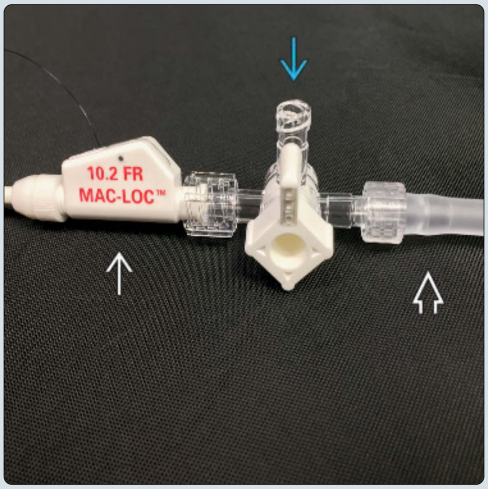
- Reported clinical success of abscess drainage > 90%
- Lower probability of success with collections that are
    - Multiloculated/phlegmonous
    - Associated with fistula/downstream obstruction
- Catheter removal criteria
    - Fever/leukocytosis resolved; stable patient
    - Drain output < 10-20 mL/day; no fistula

(Left) *The typical pigtail drain (shown here) is formed and held in place with a string* ⇨ *attached to the drain tip. Multiple side-holes* → *are found distal to a radiodense band* ↪. *The pigtail drain is straightened during placement with a metallic stiffening cannula* → *for straight, over-wire advancement through dense tissues, a plastic cannula* ⇨ *which can track over a slightly curved wire, or a sharp trocar* ↪. **(Right)** *3-way stopcock is open from drain* → *to collection bag tubing* ⇨. *Off to flush port* →.

Pigtail Drain Catheter



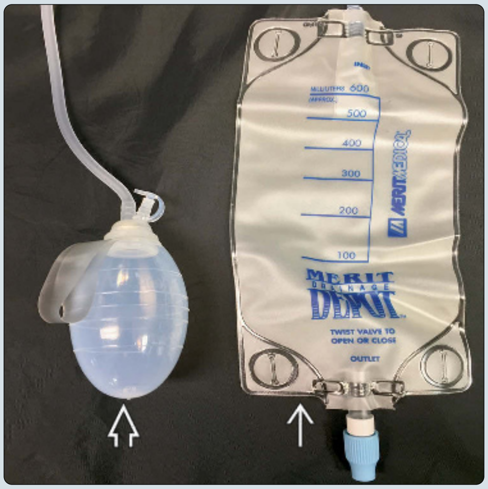
3-Way Stopcock



(Left) *After placement, drain catheters can be adhered to the skin with suture or with an adhesive securing device such as this.* **(Right)** *Gravity bag* → *and suction bulb* ⇨ *(a.k.a. JP, or Jackson Pratt) are 2 common drainage collection devices. When determining which device to use, consider whether or not suction will be beneficial to the patient (e.g., many proceduralists prefer to avoid suction when a fistula to bowel is present) and the volume of drainage expected.*

Drain Catheter Securement Device

Drainage Collection Devices



TERMINOLOGY

Definitions

- **Aspiration**: Removal of fluid by needle or catheter
- **Drainage**: Fluid removal with catheter left indwelling
- **Seldinger technique**: Tracking drain into collection over wire that has been previously advanced into collection through hollow access needle
    - Advisable in small, deep collections with limited access
    - Inexperienced proceduralists may find controlling wire difficult while advancing drain, resulting in lost access or malpositioned drains
- **Trocar technique**: Advancing drain directly into collection over sharp inner stiffener
    - One-stick, typically shorter duration than Seldinger
    - Often used for shallow, larger collections
    - Tandem-trocar: Advancing drain in-parallel alongside smaller guiding needle
- **Transabdominal (TA) approach**: Generally shortest route, most easily tolerated by patients
- **Transgluteal (TG) approach**: To access to deep pelvic structures obscured by anterior bowel
    - Must choose route close to sacrococcygeal margin to avoid neurovascular structures
    - Often painful approach
- **Transrectal (TR) approach**: To access prostatic abscess or collections anterior/posterior to rectum
- **Transvaginal (TV) approach**: To access pelvic collections anterior to rectum
    - TV/TR catheters have highest risk of falling out

PREPROCEDURE

Indications

- Fluid characterization
    - Abscess, ascites, biloma, empyema, effusion, hematoma, lymphocele, seroma, urinoma
- Treatment
    - Often curative with abscess
    - May be temporizing in complex or peripancreatic collections
    - Allows sclerosis of recurring cysts or collections
- Alleviation of symptoms
    - Pressure/pain of large hepatic/renal cysts, pancreatic pseudocysts

Contraindications

- Lack of safe access
    - Intervening bowel, vessels, or certain viscera
- Uncorrectable coagulopathy
- Tumor abscesses
    - May require lifelong drainage catheter
        - Requires patient, family, clinician understanding
- Echinococcal cysts
    - Risk of anaphylaxis

Preprocedure Imaging

- Review preprocedure imaging
    - Visualize abnormality and adjacent structures
    - Plan access route to collection
        - Typically, shortest path that avoids intervening structures
            - Transenteric route may be appropriate for needle aspiration, but not drain placement
            - Transhepatic drainage can be effective; avoid large vessels/dilated ducts
            - Transpleural drainage of abdominal collections risks pneumothorax/pleural effusion
        - TV/TR catheter has highest risk of falling out
        - Localize arteries along chosen path
    - Select imaging guidance method for drainage
        - **US**
            - Allows real-time visualization of anatomy and access
            - Allows localization of adjacent vascular structures
            - Permits portable procedures
            - Permits TV, TR access
            - No radiation exposure
            - Limited by body habitus, bone, and bowel gas
        - **CT**
            - Better visualization of fluid collection and intervening structures; ideal for deep, small collections
            - Time consuming and expensive
            - Limited by inability to scan during manipulation of access needles, wires and drains
            - Real-time information with CT fluoroscopy; radiation exposure may be of concern
            - Referring service often comfortable reviewing images to better understand procedure and plan care
        - **Fluoroscopy**
            - Often used in conjunction with US-guided access
            - Allows real-time visualization of procedure
            - Allows contrast injection to localize fistula

Getting Started

- Things to check
    - Clinical history and physical examination
        - Procedure indications
        - Current medications
            - Any anticoagulant or antiplatelet agents
    - Allergies
    - Coagulation status
        - New drain placement: Moderate risk
            - International normalized ratio (INR) recommended; correct to ≤ 1.5
            - Platelet count recommended; correct to > 50,000/μL
            - Activated partial thromboplastin time (aPTT) recommended; trend toward correcting values ≥ 1.5x control
            - Clopidogrel: Hold 5 days prior to procedure
            - Aspirin: Do not hold
            - Low molecular weight heparin (LMWH): Hold 1 dose prior to procedure
        - Over-wire exchange of existing drain: Low risk
            - INR recommended for patients receiving warfarin; correct < 2.0
            - Platelet count not routinely recommended; if known, correct to > 50,000/μL

            - aPTT recommended; no consensus for correction
            - Otherwise same as new drain placement
        - Hematocrit not routinely recommended
    - Special considerations
        - Adnexal fluid collections: Consult with gynecologic oncology prior to drain placement in suspected malignant adnexal fluid collections
- Medications
    - Anesthesia
        - 1% lidocaine local anesthetic
        - Use procedural sedation as necessary
            - Typically fentanyl, midazolam used
            - Drain placement to deep pelvic or infected collections can be quite painful; discuss sedation plan with procedural nurse prior to case
    - Prophylactic antibiotics
        - Referred patients are often receiving antibiotics
        - Consider for symptomatic patients
        - Tailor to patient allergies and prior cultures
        - Typical polymicrobial, broad-spectrum choices
            - 1-2 g cefoxitin IV every 6-12 hours
            - 1 g ceftriaxone IV every 24 hours
            - Ampicillin (1 g) and gentamicin (80 mg)
            - Levaquin (500 mg)
- Equipment list
    - General
        - US equipment
            - 2- to 12-MHz transducer (location dependent)
            - Sterile probe cover/gel
        - Fluoroscopy equipment
            - Useful adjunct to US-guided procedures
        - CT equipment
            - Radiopaque grid
    - Trocar technique
        - 8- to 14-Fr trocar-mounted locking pigtail catheter
    - Tandem trocar technique
        - 20-g Chiba guiding needle
        - 8- to 14-Fr locking pigtail catheter
    - Seldinger technique
        - Access needle (e.g., 18-g needle, 18-g Longdwell needle, 19-g ultra-thin Chiba needle)
        - 0.035" guidewire with 3-mm J-tip
        - 8- to 14-Fr dilators as appropriate
        - 8- to 14-Fr locking pigtail catheter
    - TV or TR approach
        - Endovaginal/endorectal transducer
        - 2 sterile probe covers and rubber bands
        - Sterile gel
        - Plastic protector for locking pigtail catheter
        - Speculum for TV approach
    - Paracentesis or thoracentesis
        - 18- to 22-g spinal needle (diagnostic aspiration)
        - 7-Fr curved-tip catheter (therapeutic aspiration)

PROCEDURE

Patient Position/Location

- Best procedure approach
    - General: Shortest route that avoids intervening structures
        - General preference order for approach
            - TA > TG > TV/TR
    - TA approach: Supine if possible
        - Decubitus or prone if necessary
            - To shift intervening structures such as bowel, giving clear access to collection
            - Decubitus position may reduce risk of pleural transgression by splinting ipsilateral hemithorax
    - TG approach: Decubitus or prone positioning
    - TV approach: Dorsal lithotomy position
    - Transrectal approach: Left lateral decubitus position

Procedure Steps

- **General**
    - Review preprocedure images; verify
        - Target collection visualized with chosen imaging guidance modality
        - Safe route to collection
            - i.e., no intervening arteries
- **Imaging modality specifics**
    - CT guidance
        - Perform preliminary scan with radiopaque grid
        - Plan access route; change patient position if necessary to avoid intervening structures
        - Mark entry site on skin
        - Administer 1% lidocaine local anesthetic
        - Make dermatotomy with #11 scalpel blade
        - Advance access needle into collection
            - 18-g Chiba/ring needle (planned Seldinger technique)
            - 20-g guiding needle (planned tandem trocar technique)
        - Aspirate small amount of fluid; inspect color, purulence, viscosity
        - Select catheter size; large/viscous collections more effectively drained by larger catheters (12-14 Fr)
    - US guidance
        - Apply gel on probe: Place sterile cover on transducer
        - Apply sterile gel externally over probe cover
        - Image target collection; reconfirm planned route
        - Apply 1% lidocaine local anesthetic
        - Make dermatotomy with #11 scalpel blade
        - Advance access needle into collection
            - 18-g Chiba/ring needle (planned Seldinger technique)
            - 20-g guiding needle (planned tandem trocar technique)
        - Aspirate small amount of fluid; inspect color, purulence, viscosity
        - Select catheter size; large/viscous collections more effectively drained by larger catheters (12-14 Fr)
    - Fluoroscopic guidance
        - Access usually obtained with US guidance
        - Needle advancement as described above
            - Contrast can be injected to confirm borders of collection and to look for fistula
        - Follow with Seldinger or Trocar technique
            - Seldinger technique may allow wire to track from superficial collection to deeper communicating space

- **Technique specifics**
  - **Seldinger technique**
    - Advance 18-g needle into collection
    - Advance 0.035" guidewire into collection via needle
      - Confirm position of wire in collection with CT
      - Stiff wire (e.g., Amplatz) if passing through dense tissue and collection well formed (not typically for intrahepatic/intrarenal collections)
      - Less-stiff wire with rounded tip (e.g., Rosen, 3J) for smaller, less well-formed, or in-organ collections (wire less likely to perforate capsule of collection); greater risk of wire kink during drain advancement; combat with very slight traction on wire during drain advancement
    - Measure distance of needle from skin to collection
    - Serially dilate tract (by measured distance) over guidewire to appropriate diameter for selected catheter size
    - Load catheter onto stiffening cannula
    - Mark measured distance on catheter
    - Advance catheter assembly over guidewire by measured distance
      - Unscrew inner stiffening cannula
      - Stabilize cannula so it does not advance
      - Advance catheter further into collection, allowing it to track over wire
    - Remove stiffener and guidewire; lock pigtail
    - Aspirate fluid, send to lab if appropriate
    - Confirm position ± contrast; caution injecting through newly placed drain, can result in bacteremia/sepsis
  - **Direct trocar technique**
    - Load locking pigtail catheter over trocar
    - Additional 1% lidocaine, dissect bluntly
    - Advance catheter assembly into collection with real-time US guidance
    - Unscrew trocar from catheter
    - Hold trocar so no longer advances, advance catheter off of trocar further into collection
    - Remove trocar, form pigtail tip within fluid collection, lock pigtail
    - Aspirate fluid, send to lab if appropriate
    - Visualize pigtail in collection with US
  - **Tandem trocar technique**
    - Review preliminary CT images
      - Measure distance of skin to collection
      - Evaluate adjacent structures (e.g., arteries) along planned trajectory
      - Select location along 360° axis around needle hub, through which catheter/trocar will be advanced in tandem to needle; choose safest path based on CT images
    - Advance 20-g guiding needle into collection
    - Load catheter onto trocar
    - Additional 1% lidocaine, dissect bluntly
    - Mark measured distance to collection on catheter
    - Advance catheter assembly in tandem, parallel to guiding needle by measured distance
    - Unscrew trocar and, while holding trocar in place, advance catheter into collection
    - Remove trocar, lock pigtail
    - Aspirate fluid, send to lab if appropriate
    - Confirm position with CT
- **Approach specifics**
  - **TG approach**
    - Needle entry site as close as possible to sacrococcygeal margin to avoid neurovascular structures
    - Use infrapiriformis approach if possible (less painful)
    - Angling gantry may help achieve best access
  - **TV and TR approach**
    - Consider Foley catheter to decompress bladder
    - Perform preliminary imaging with endovaginal/endorectal probe
      - Verify adequate visualization of collection
      - Doppler to assess for intervening vessels
    - TV: Wash vaginal vault with preparatory solution
    - Place sterile probe cover; secure with rubber band
    - Use plastic protector in which pigtail catheter packaged as guide and needle/catheter holder
      - Shorten protector so catheter will protrude 5 cm
      - Cut longitudinal slit along length of protector
      - Attach plastic protector to probe; secure with distal and proximal rubber bands
    - Place 2nd sterile probe cover over assembly
    - Insert probe assembly into vagina/rectum
    - Visualize collection; confirm safe path with Doppler
    - Aspiration may be performed initially with needle; advance 20-g needle through plastic protector attached to probe into collection under real-time US, aspirate fluid
    - Load 8- to 10-Fr locking pigtail catheter onto inner cannula and sharp stylet (trocar)
    - Advance catheter assembly through plastic protector into collection
    - Unscrew trocar; advance catheter 2-3 cm while holding trocar in place; allow pigtail to form
    - Remove sharp stylet
    - Cut distal rubber band and peel off outer sterile probe cover
    - Remove probe; cut remaining rubber band
    - Peel off plastic protector
    - Remove inner stiffener from catheter
    - If aspiration only, aspirate all fluid, confirm with US, and remove catheter
    - If indwelling catheter is to be left in, secure to medial thigh
- **Specific applications**
  - **Adnexal collections**
    - Gynecologic consultation prior to aspiration/drainage in suspected malignancy
    - Aspiration: Only of tuboovarian abscesses
      - May be effective, but drainage is generally preferred to avoid need for repeat procedure
  - **Ascites**
    - Most common causes: Cirrhosis, malignancy
    - Determine lab tests to send on aspirated fluid
      - Most common: Gram stain, cytology, fluid cell count, culture, albumin, protein
    - Use US to document fluid location/volume/depth
      - Choose site with largest fluid volume, no intervening viscera

        - Most common location: Right lower quadrant
    - Color Doppler to assess for intervening vessels (e.g., inferior epigastric)
    - Administer local anesthetic from skin to peritoneum
        - Aspirate fluid to confirm in peritoneal space
    - **Diagnostic paracentesis**
        - 18- to 22-g spinal needle
        - Small-volume ascites: Advance needle under real-time US guidance
        - Large-volume ascites: Mark skin entry site selected by US and advance needle
    - **Therapeutic paracentesis**
        - Cirrhotic patients may have hemodynamic consequences from large-volume tap; may require serum albumin resuscitation after
        - Consider 5 L maximum volume aspirated for 1st-time paracentesis and in cirrhotics
        - Nick skin with #11 scalpel blade at entry site
        - 7-Fr curved-tip catheter loaded on trocar
        - Advance catheter-trocar assembly using US or by measured depth
        - Peritoneal puncture delineated by "pop"
        - Unscrew catheter from trocar, advance into peritoneal space
        - Attach 3-way stopcock and extension tubing
        - Obtain diagnostic specimens by 3-way stopcock
        - Attach tubing to vacuum-drainage bottles
- **Kidney**
    - Obtain fluid creatinine in suspected urinomas
    - If urinary obstruction/persistent drain output
        - May require nephrostomy/ureteral stent or nephroureteral catheter
- **Liver**
    - Pyogenic abscesses/bilomas most commonly drained hepatic collections
    - Refractory echinococcal cysts may be drained after 2 weeks of medical therapy
    - Refractory amebic abscesses may also be drained
    - Avoid pleura, large vessels, dilated ducts
        - Angling gantry may help achieve optimal access
    - Obtain bilirubin on perihepatic collections to confirm/exclude biloma
- **Pancreas**
    - Pseudocysts
        - > 5 cm; enlarging or symptomatic
    - Aspiration to assess for infection
    - Drainage may be performed for infected or symptomatic collections
        - Phlegmon may be too viscous for drainage
        - Temporizing before surgery
    - Send fluid amylase on peripancreatic collections
- **Subphrenic collections**
    - Consider US with fluoroscopy vs. CT for guidance
    - Pleural transgression may be unavoidable
        - Angling CT gantry may provide optimal access
        - Check for pneumothorax on post-CT images
        - Avoid transgression of lung parenchyma
    - Check amylase if left subphrenic fluid collection

- **Postdrainage**
    - **Irrigation**
        - Attach 3-way stopcock/drainage bag to catheter
        - Aspirate all contents from cavity
        - Irrigate with sterile normal saline
            - Irrigant volume should be less than cavity size
            - Overdistention risks bacteremia
            - Irrigate until clear or blood-tinged aspirate
        - Repeat US or CT
            - Confirm all fluid drained
            - Undrained fluid may be due to loculation; may require additional catheters
    - **Catheter fixation**
        - Internally secured by locking pigtail
        - Externally secured by
            - Commercial fixation device
            - Piece of tape placed around catheter near entry site; sutured to adhesive disk placed on skin

Alternative Procedures/Therapies

- Surgical
    - Laparoscopic drainage
    - Open surgical drainage
- Other
    - Endoscopic aspiration/drainage
        - Peripancreatic fluid collections (e.g., pseudocysts)

POST PROCEDURE

Drain Catheter Removal Criteria

- Resolution of fever and leukocytosis
- Drainage catheter output < 10-20 mL/day
- No fistula or large cavity on catheter injection
- No cavity on available cross-sectional imaging
    - May need to obtain imaging if no output, but residual signs/symptoms of infection
- Hemodynamically stable

Things to Do

- Send sample to lab; request studies based on differential diagnosis
    - Abscess: Gram stain, culture, sensitivity
    - Biloma: Bilirubin
    - Peripancreatic collection: Amylase
    - Urinoma: Creatinine
- Record drain output per shift
- Flush catheter with 10 mL normal saline every 8-12 hours
    - 5 mL to cavity; 5 mL to drainage bag via 3-way stopcock
        - Prevents clogging of catheter/tubing
    - More frequent flushes if fluid tenacious
    - Always flush after aspiration
- Follow-up Gram stain and culture

Things to Avoid

- Repetitive CT imaging
    - Consider clinical scenario/impact of additional imaging on catheter management
    - May have substantial cumulative radiation dose (e.g., patients with inflammatory bowel disease, recurrent pancreatitis, biliary obstructive disease)
- Do not remove catheter early if
    - Undrained fluid, persistent output
    - Persistent fever, leukocytosis

OUTCOMES

Problems

- **Low drainage output**
  - Consider potentially dislodged/malpositioned drainage catheter, undrained loculations, tenacious fluid or phlegmon
  - Reimage if low drainage output and persistent fever, leukocytosis, or hemodynamic instability
    - Consider contrast injection under fluoroscopy; if malpositioned
      - Reposition drain over guidewire
      - Place new drain if tract not salvageable
      - If fluid viscous, exchange and upsize drain
      - Use catheter with as many sideholes as possible; higher clinical success rate with more sideholes
  - Deliver intracavitary tissue-type plasminogen activator (tPA)
    - Useful for viscous contents and persistent fluid collection despite good catheter position
      - Success rate > 80% in such collections
    - 4-6 mg tPA in 25 mL sterile normal saline
    - Instill tPA into cavity; clamp catheter for 30 min
    - Unclamp and do not aspirate
    - If multiple catheters in collection, divide dose
    - May be used even if systemically anticoagulated
- **Persistent high drainage output**
  - Likely related to fistula
    - Management requires patience, often months
    - Octreotide for pancreatic fistula
    - Address any downstream obstruction

Complications

- Most feared complication(s)
  - Hemorrhage
    - Review imaging for intervening vasculature
    - Doppler sonography when applicable
  - Septic shock: Give broad-spectrum antibiotics
- Immediate/periprocedural complication(s)
  - Hemorrhage
  - Sepsis
  - Pneumothorax
    - Avoid pleural transgression if possible
    - Observe if small and clinically silent
    - Low threshold for chest tube insertion
- Delayed complication(s)
  - Dislodged catheter
  - Peritonitis
  - Hemorrhage
  - Pleural effusion (if transpleural catheter)
- Other complications
  - Visceral injury
    - Bowel
      - If inadvertent traversal of bowel by catheter, may withdraw catheter into bowel lumen
      - Wait 2 weeks for tract maturation prior to catheter removal
    - Bladder
      - May require Foley decompression

Expected Outcomes

- Reported clinical success of abscess drainage > 90%
- Lower probability of success with certain collections
  - Multiloculated
  - Phlegmonous
  - Associated with fistula/downstream obstruction
- Prognostic factors associated with primary failure
  - High residual volume of fluid after drainage
  - CT attenuation > 20 HU
  - Presence of fistula

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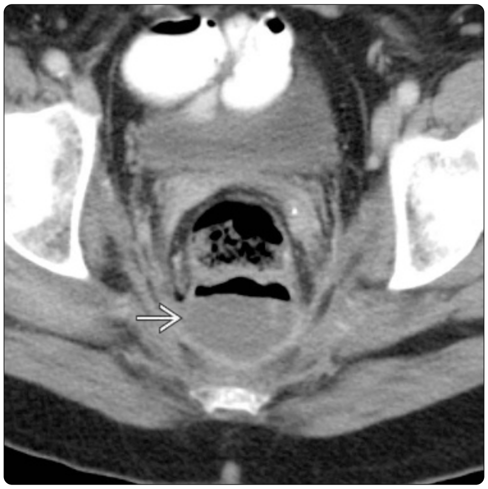
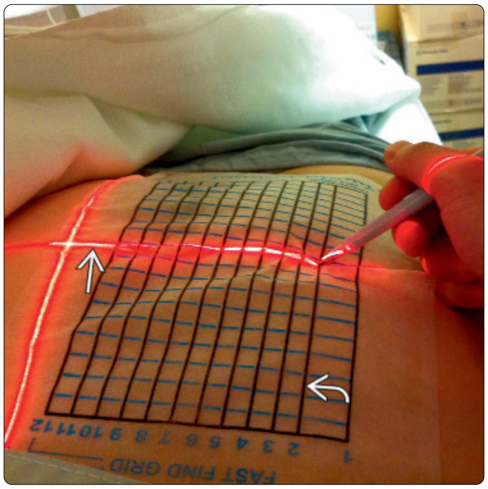
(Left) *Axial CECT of a 64-year-old woman with diverticulitis demonstrates a 6 x 4-cm air and fluid collection* ➡ *located in the presacral space.* **(Right)** *A localizing grid helps select the appropriate point for placing the drainage catheter. The red laser line* ➡ *demarcates a specific slice position, while radiopaque lines* ➡ *can be seen on preliminary CT imaging. A pen is used to mark the exact entry site.*

Step-by-Step: Presacral Abscess (Initial CECT)

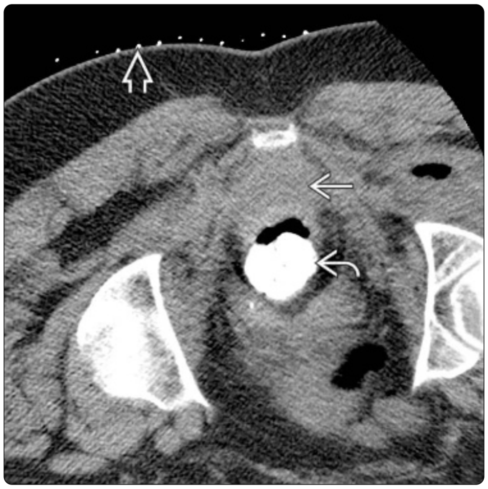


Step-by-Step: Presacral Abscess (Site Selection)

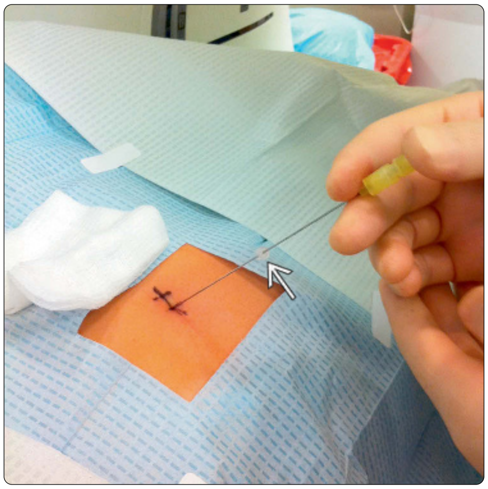


(Left) *Axial CT with the patient in the prone position reveals the radiopaque grid lines* ➡ *placed on the skin. The rectum* ➡ *has been filled with contrast to differentiate it from the presacral abscess* ➡*. Structures along the planned infrapiriformis approach are carefully scrutinized.* **(Right)** *The area is prepared and draped, and local anesthetic is applied. In tandem trocar technique, a 20-g guiding Chiba needle is advanced the distance to the abscess* ➡*, with intermittent CT imaging to confirm needle tip location.*

Step-by-Step: Presacral Abscess (CT Localization)

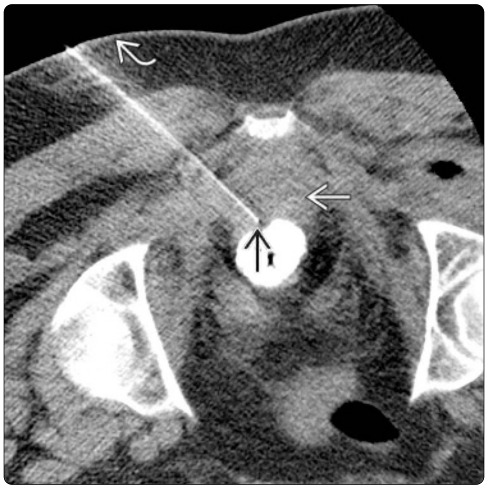


Step-by-Step: Presacral Abscess (Tandem Trocar Technique, Guiding Needle)

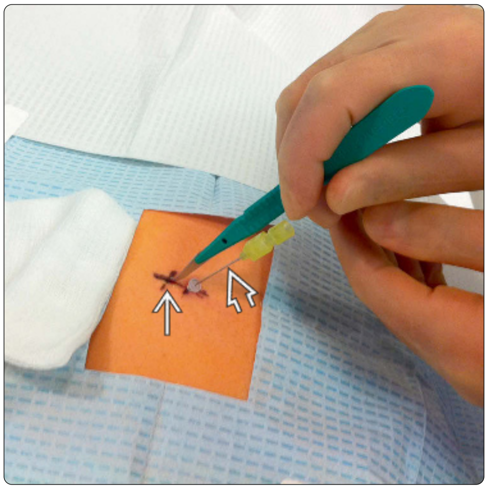


(Left) *Axial NECT shows the tip* ⇨ *of the guiding needle located within the abscess* ➡*. An appropriate skin entry site* ➡ *is then selected to be used for tandem placement of the trocar-mounted drainage catheter.* **(Right)** *A skin nick is made with a scalpel at the selected skin access point* ➡*. The trocar-mounted drainage catheter will be introduced via the nick and advanced in tandem to the guiding needle* ➡*.*

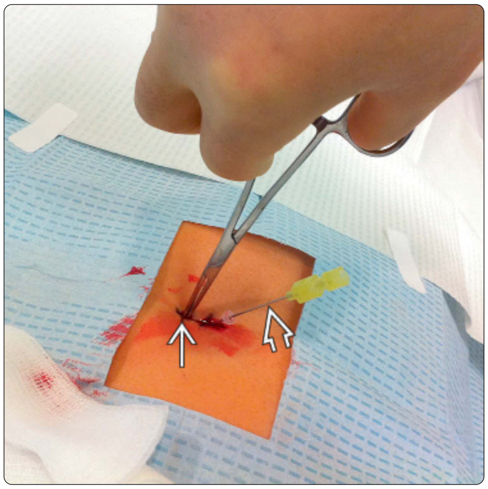
Step-by-Step: Presacral Abscess (Tandem Trocar Technique, Guiding Needle)



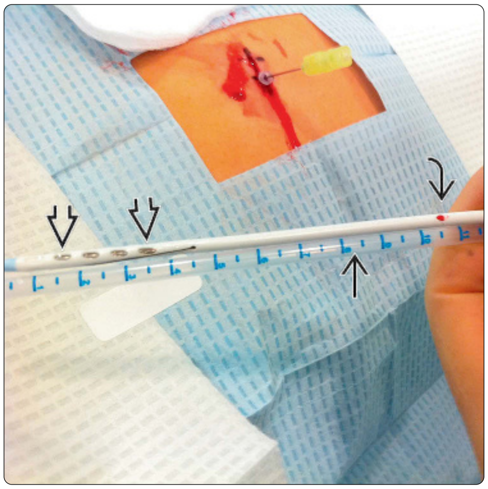
Step-by-Step: Presacral Abscess (Tandem Trocar Technique, Skin Nick)



Step-by-Step: Presacral Abscess (Tandem Trocar Technique, Blunt Dissection)

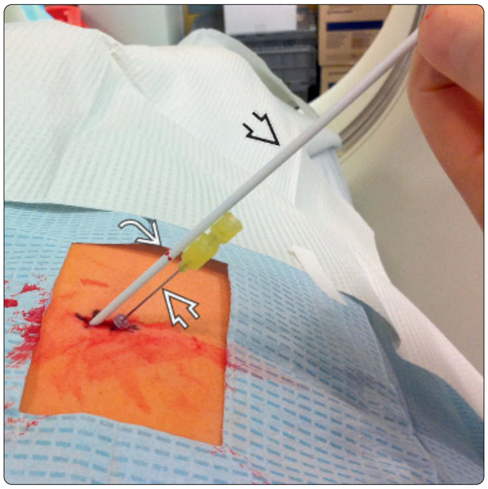


Step-by-Step: Presacral Abscess (Tandem Trocar Technique)

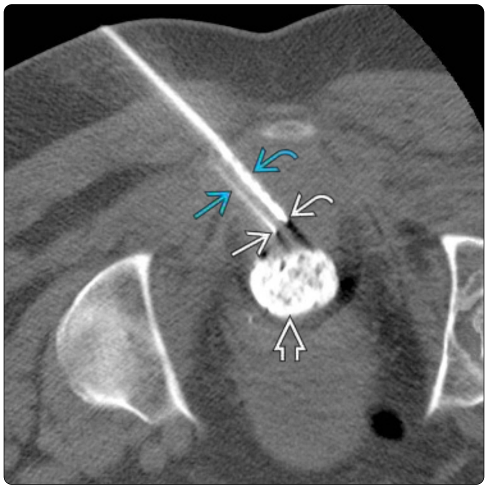


(Left) *A hemostat is used to perform blunt dissection of the subcutaneous tissues through the skin nick ➡. Note that the guiding needle ⇨ still remains in place.* **(Right)** *In preparation for its placement, a pigtail drainage catheter with multiple sideholes ⇒ is loaded onto a sharp metal trocar. The distance to the abscess, as determined on the initial CT images, is marked ↷ onto the catheter using a ruler →.*

Step-by-Step: Presacral Abscess (Tandem Trocar Technique)

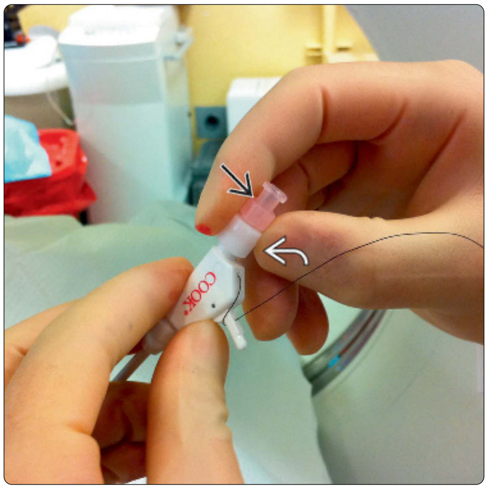


Step-by-Step: Presacral Abscess (Tandem Trocar Technique, CT Confirmation)

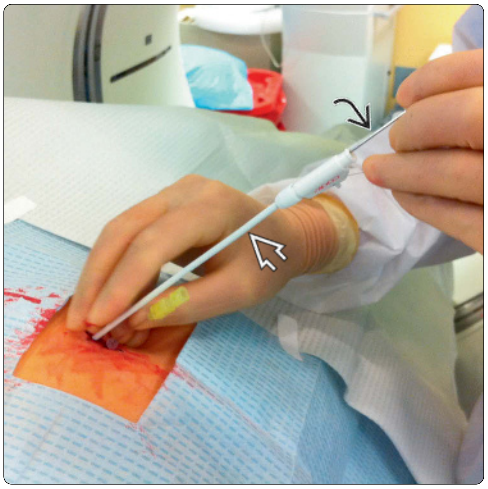


(Left) *The drainage catheter ⇒ is introduced through the skin nick & advanced parallel to the guiding needle ⇨ until the measured mark on the catheter is reached ↪.* **(Right)** *Axial NECT obtained following introduction of the trocar-mounted drainage catheter shows satisfactory position, with the tip anterior to the rectum ⇨ & within the abscess. Note that the drainage catheter tip ↪ is directly adjacent to that of the guiding needle ➡ and that the courses of the needle → and catheter ↷ are parallel.*

Step-by-Step: Presacral Abscess (Drain Catheter Deployment)



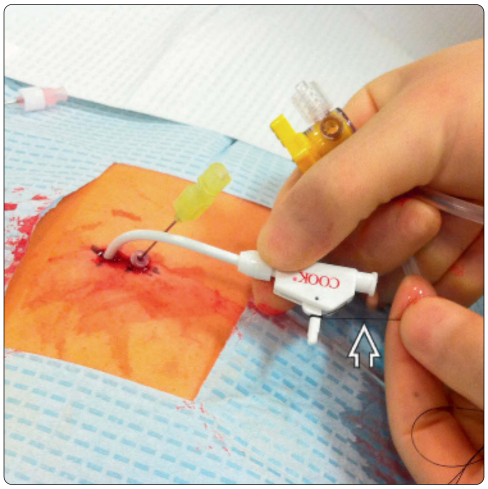
Step-by-Step: Presacral Abscess (Drain Catheter Deployment)



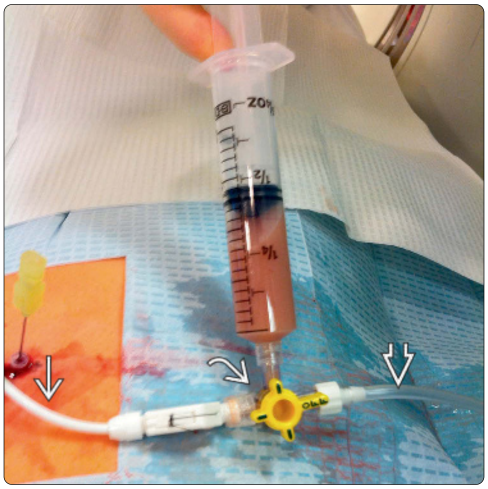
(Left) *Once the drain tip is in satisfactory position, the inner metal stiffener → is unscrewed ↪ from the drainage catheter, but the stiffener is not removed.* **(Right)** *While maintaining a stationary position to the inner stiffener ↷, the drainage catheter ⇨ is advanced over the stiffener into the abscess collection, thereby allowing the pigtail configured tip of the catheter to reform within the collection. The sideholes adjacent to the catheter tip should lie within the abscess.*

(Left) *After advancing the drainage catheter into the abscess collection, the inner stiffener was removed. The pigtail tip is then locked and held by tightening a intraluminal suture ⇨. The drain will not straighten without releasing this suture.* **(Right)** *One end of a 3-way stopcock ↪ is attached to the catheter → and the other to extension tubing ⇨, which is connected to a drainage collection bag. A syringe is attached to the side port of the stopcock and used to aspirate all purulent fluid from the abscess collection.*

Step-by-Step: Presacral Abscess (Drain Catheter Deployment)

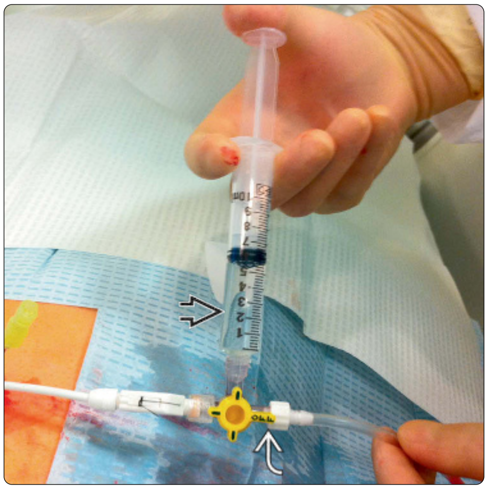


Step-by-Step: Presacral Abscess (Aspiration)

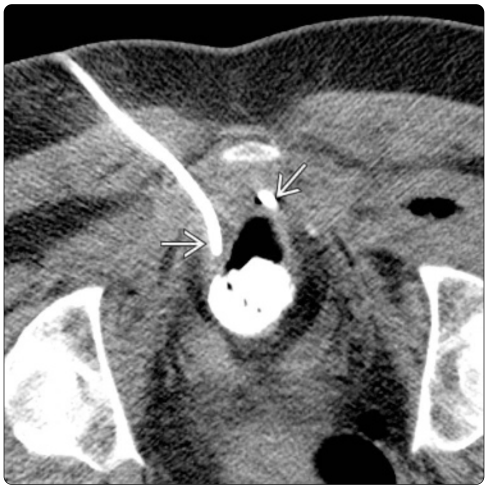


(Left) *The cavity is then carefully irrigated with sterile normal saline ⇒ until no further debris can be aspirated, or until the aspirate becomes blood-tinged. During injection, the 3-way is off ↪ to the drainage bag.* **(Right)** *Following aspiration and irrigation of the abscess cavity, a final CT can be obtained to document final drainage catheter tip position → and to confirm that there is no residual undrained component to the abscess collection. Note that the guiding needle has been removed.*

Step-by-Step: Presacral Abscess (Irrigation)

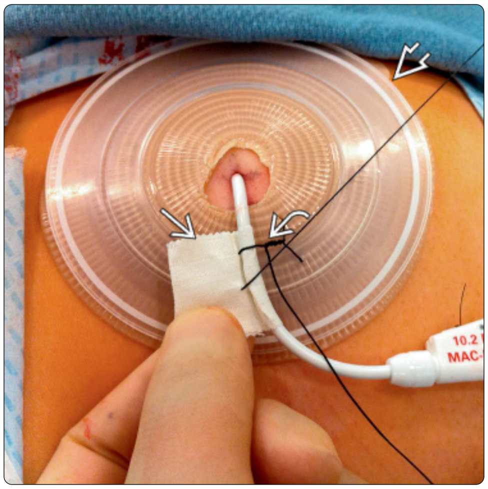


Step-by-Step: Presacral Abscess (CT Confirmation)

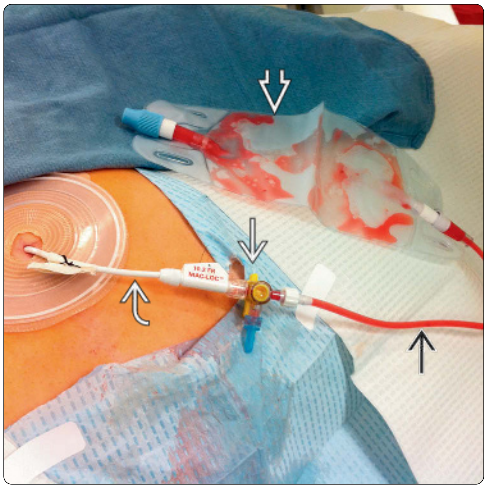


(Left) *Multiple drain-securing devices are available. In this case, the drainage catheter was threaded through an adhesive disk ⇨ attached to the skin. A piece of fabric tape → is placed around the catheter and then sutured ↪ to the disk.* **(Right)** *A 3-way stopcock → is left in place to allow for regular flushing of the drainage catheter ↪. Extension tubing ⇾ attached to the other end of the stopcock is connected to a gravity drainage bag ⇨. The stopcock is left open to permit continuous drainage into the collection bag.*

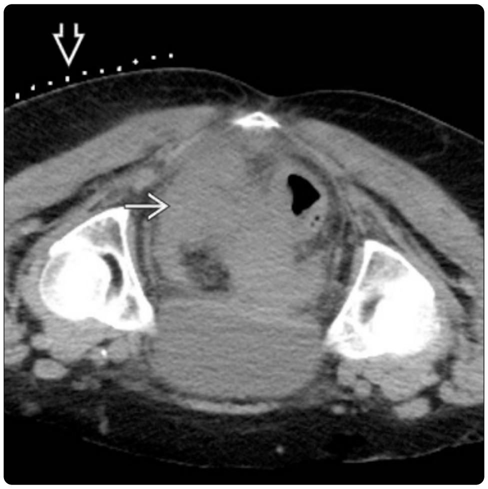
Step-by-Step: Presacral Abscess (Drain Fixation)



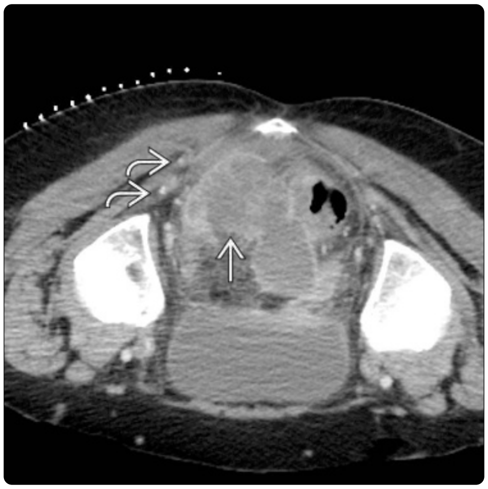
Step-by-Step: Presacral Abscess (Final Drainage Assembly)



Presacral Abscess: Seldinger Technique (CT Localization)

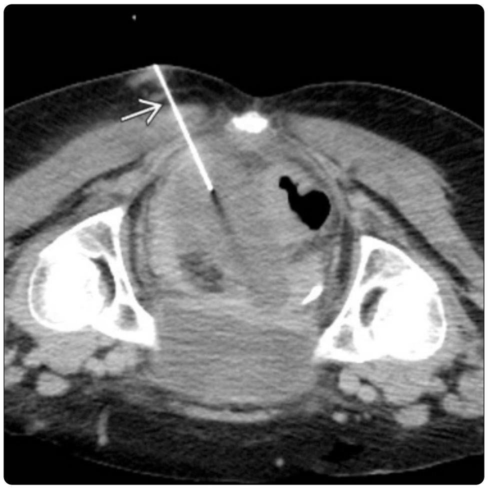


Presacral Abscess: Seldinger Technique (CECT Localization)

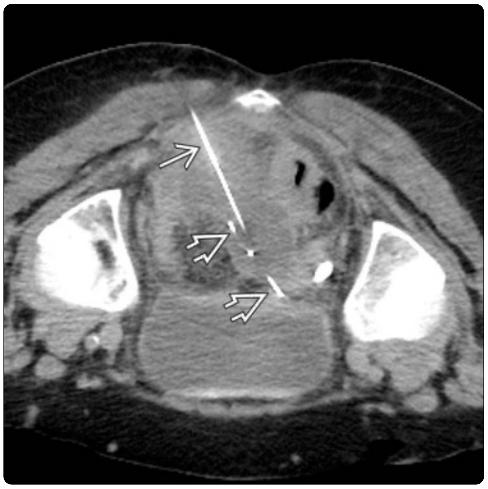


(Left) *Patient with a presacral abscess was positioned prone, and a localizing CT was obtained with a grid ➡ on the skin. Unfortunately, these images could not exclude the presence of bowel in the target area adjacent to the abscess ➡.* **(Right)** *Following IV administration of 100 cc iodinated contrast, the rim-enhancing collection ➡ is clearly defined, and potentially complicating arteries ➡ are identified. No bowel is in the immediate target area.*

Presacral Abscess: Seldinger Technique (Percutaneous Access)

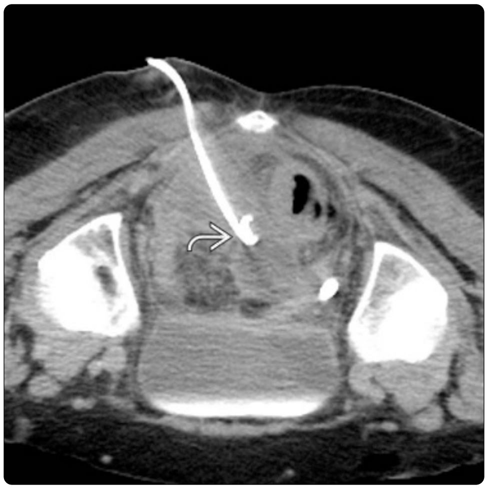


Presacral Abscess: Seldinger Technique (Wire Advancement)

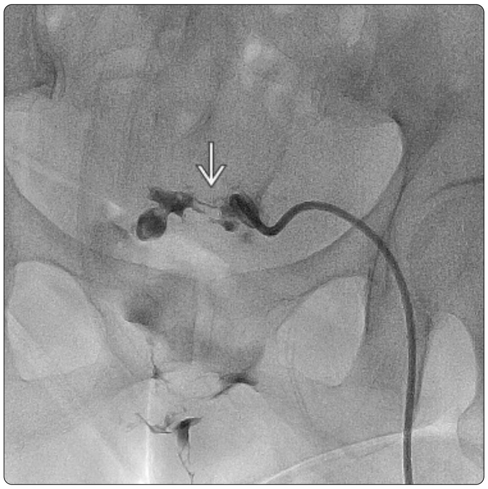


(Left) *An 18-g Chiba needle ➡ has been percutaneously advanced into the pelvic collection, using intermittent CT imaging, and using a path close to the sacrum.* **(Right)** *An 0.035" guidewire ➡ (typically Amplatz or Rosen) is advanced through the 18-g needle ➡ and coiled within the collection. As the guidewire advances, the operator feels gentle resistance against wire advancement, which abates as the wire coils.*

Presacral Abscess: Seldinger Technique (Over-the-Wire Drain Advancement)



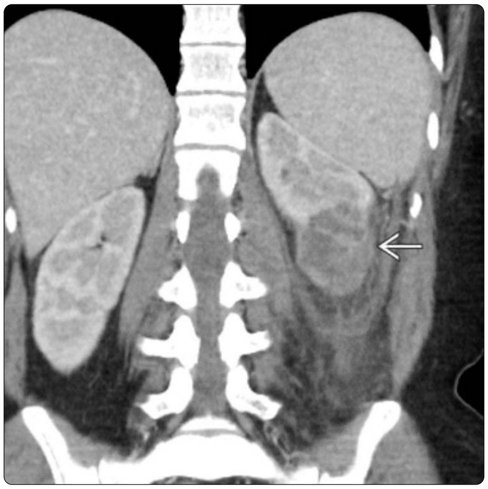
Presacral Abscess: Seldinger Technique (Follow-Up Imaging)



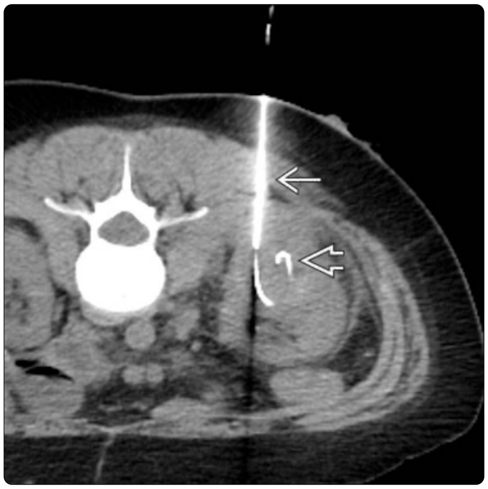
(Left) *The distance from skin to the center of the collection is measured with CT. The percutaneous tract is dilated (optional) and the drain is advanced over the wire. Advancing the drain over the metallic stiffening cannula is appropriate since the tract is straight and the traversed tissues dense. Final imaging shows the drain ➡ well positioned.* **(Right)** *After 5 days, drainage was minimal. Prior to removal, contrast was injected through the drain. A fistula ➡ to bowel was revealed; the drain remained in place for 1 more week.*

(Left) *A 37-year-old woman with HIV and left renal calculi was diagnosed with sepsis and a perirenal abscess* ➡*.* **(Right)** *An 18-g Chiba needle* ➡ *was advanced into the abscess and an 0.035" wire was advanced into the collection. A Rosen wire* ➡ *was used since the curved tip helps the wire coil within the collection. An Amplatz wire is too stiff and could easily perforate outside of the collection, through the renal parenchyma.*

Perirenal Abscess (CECT)

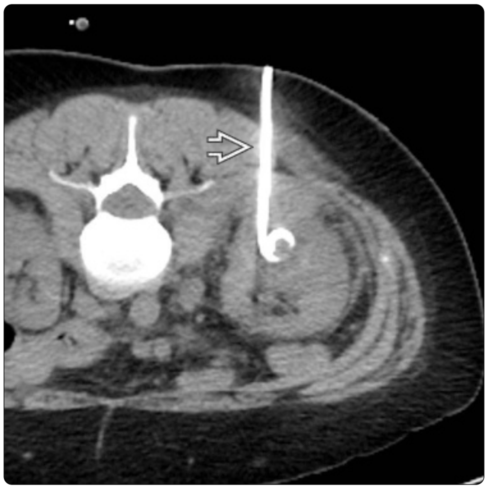


Perirenal Abscess (Seldinger Technique, Rosen Wire)

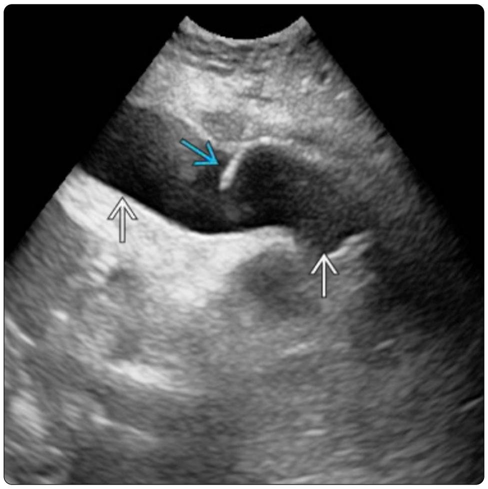


(Left) *The distance from skin to collection was measured, and a Dawson-Mueller drain* ➡ *(a drain with a narrow diameter pigtail) was advanced over a stiff, metallic inner cannula.* **(Right)** *Two weeks after receiving renal transplant, this patient was found to have peritransplant fluid collection. Due to the shallow, low-risk nature of the anterior pelvic collection, the procedure was performed entirely with US guidance. A percutaneous 18-g needle* ➡ *is seen entering the collection* ➡*.*

Perirenal Abscess (Final Drain Position)

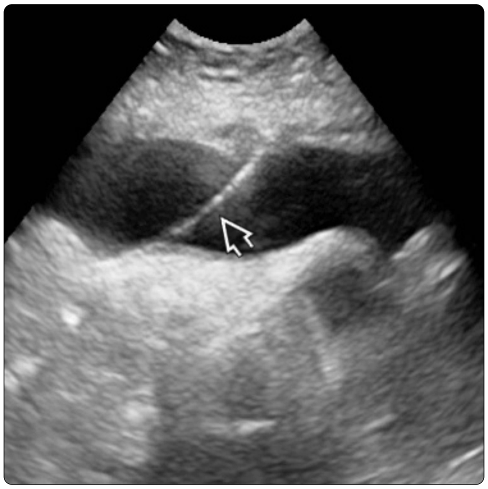


US-Guided Drain Placement (Percutaneous Needle Access)

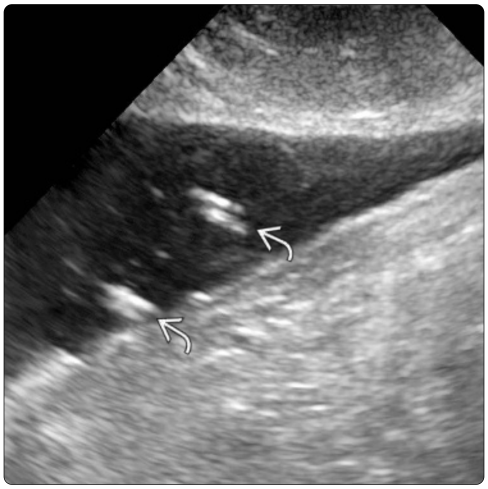


(Left) *An 0.035" guidewire* ➡ *was subsequently advanced into the collection.* **(Right)** *Percutaneous tract dilation and advancement of the drain can be performed with US guidance. It can be challenging to see the entire formed pigtail* ➡ *of the drain. Instead, it more often partially visualized, as seen here.*

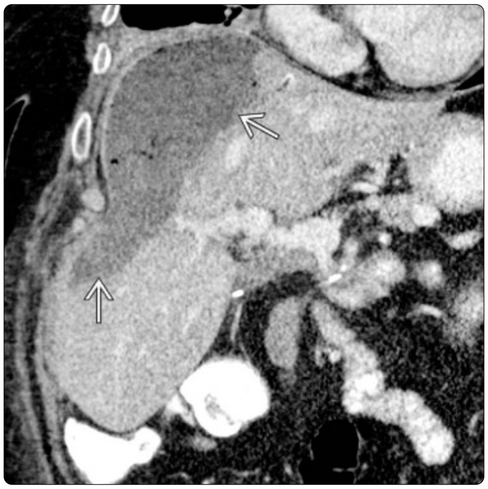
US-Guided Drain Placement (Wire Advancement into Collection)



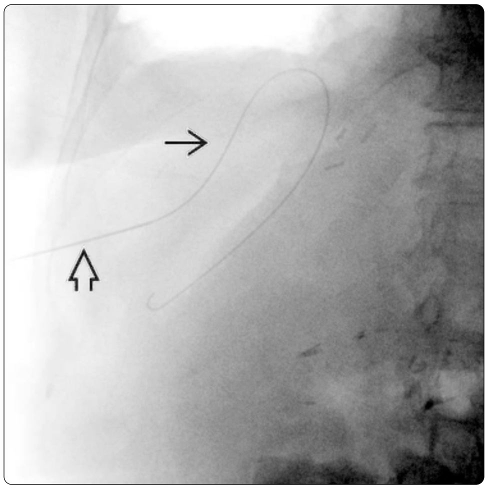
US-Guided Drain Placement (Final Position of Drain)



Fluoroscopic-Guided Drain Placement (Perihepatic Abscess)

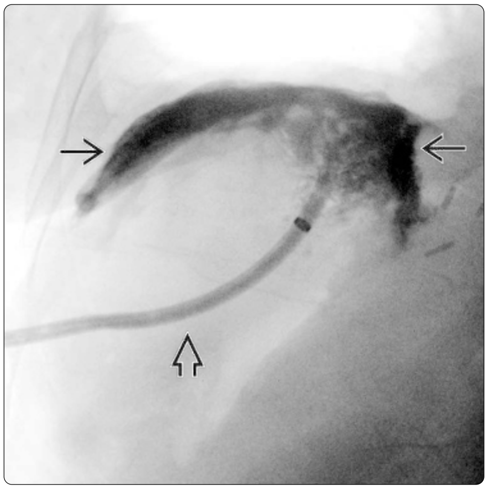


Fluoroscopic-Guided Drain Placement (Wire and Catheter Advancement)

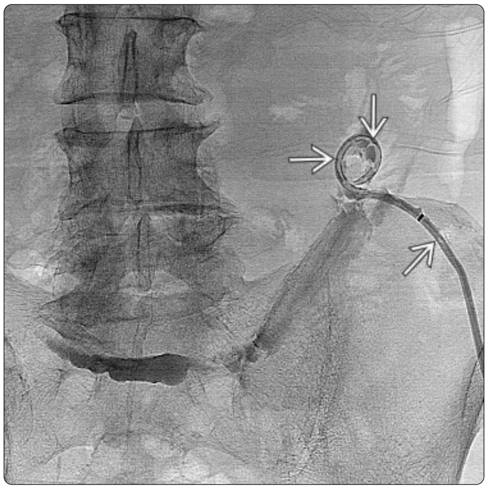


(Left) *A large, perihepatic and subphrenic collection* ➔ *is present in this patient status post cholecystectomy. Fluoroscopic-guided Seldinger technique was selected in order to lay a catheter along the entire length of the collection. US guidance was used during needle access.* **(Right)** *A guidewire* → *(Rosen) has been advanced through the needle* ⇨*. An angled catheter can help position the guidewire into the subphrenic location if needed.*

Fluoroscopic-Guided Drain Placement (Postplacement Contrast Injection)

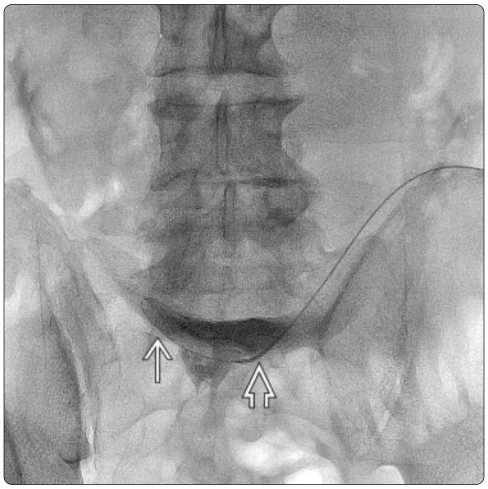


Decreased Output (Fluoroscopic Evaluation)

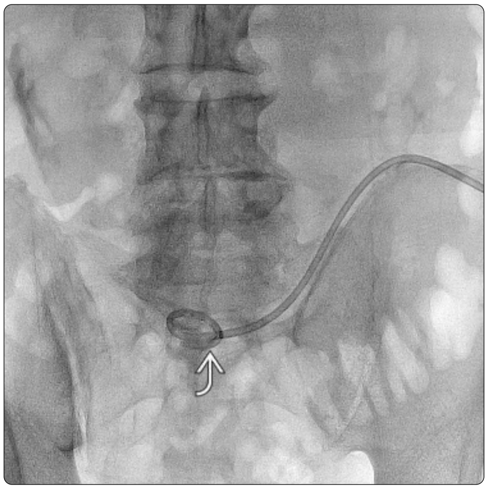


(Left) *Over the wire, the tract is dilated and a drainage catheter* ⇨ *is advanced. Contrast injected through the drain confirms satisfactory location within the abscess cavity* →*. A biliary-type drain with even more sideholes can be used to drain large collections, such as the one seen here.* **(Right)** *Output decreased significantly from this pelvic drain, and the primary service requested its removal. Contrast injected through the drain shows that the drain is partially occluded with internal debris* ➔ *and suboptimally located.*

Decreased Output (Wire Repositioning)



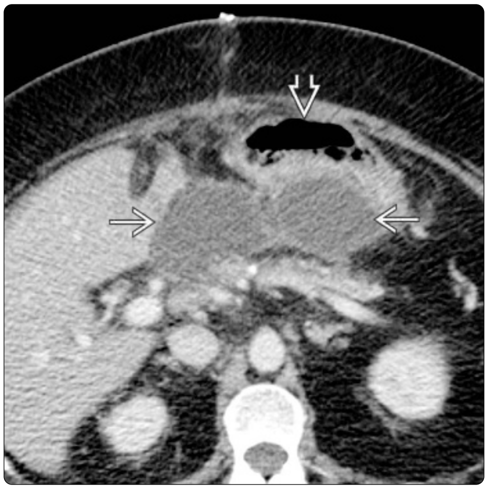
Decreased Output (Improved Drain Position)



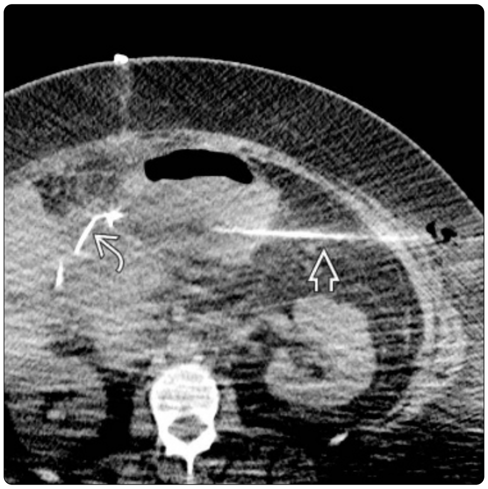
(Left) *The drain was removed over a wire, and the wire* ➔ *was repositioned via an angled catheter* ➔ *into a larger portion of the collection.* **(Right)** *A new drain* ↪ *was placed over the wire, and output significantly increased. Decreased drainage can be related to collection resolution, drain occlusion, drain malposition, septations within the collection, or equipment failure (e.g., 3-way malpositioning). To ensure that drain removal is appropriate, fluoroscopic, CT, and laboratory review is often necessary.*

(Left) *This patient status post Whipple procedure has a low-attenuation collection ➔ posterior to the stomach ⇨, consistent with a retrogastric abscess.* **(Right)** *Seldinger technique is selected in order to lay a catheter along the length of the collection. The distance from the skin to the collection is measured. A wire is advanced through a needle ⇨, which coils ↪ distally in the collection. The needle is removed and the tract dilated, with the dilator advanced no more than the measured distance.*

Retrogastric Abscess, CT-Guided Drainage (Initial CECT)

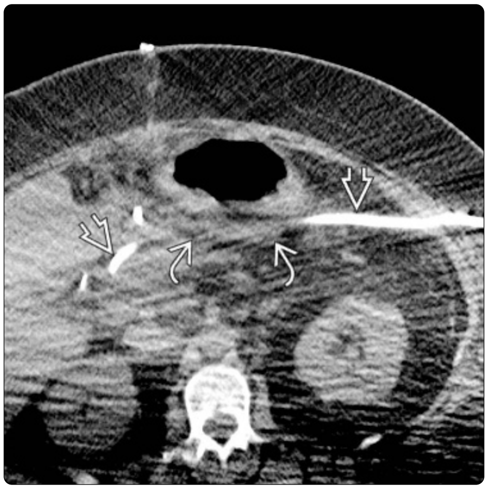


Retrogastric Abscess, CT-Guided Drainage (Seldinger Technique)

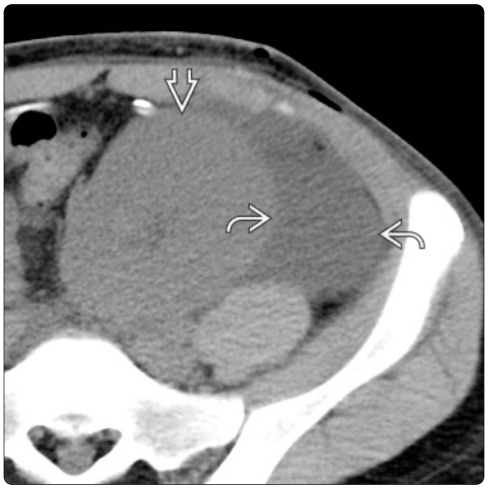


(Left) *The multiple sidehole catheter ⇨ has been advanced over the guidewire and bridges the entire length of the collection. The abscess has been completely aspirated, and the collection ↪ has collapsed.* **(Right)** *A low-attenuation fluid collection ↪ is seen within the left hemipelvis, surrounding a renal allograft ⇨. In a patient with pain, leukocytosis, and declining renal function, this was felt to most likely represent a perinephric abscess.*

Retrogastric Abscess, CT-Guided Drainage (Final Drain Position)

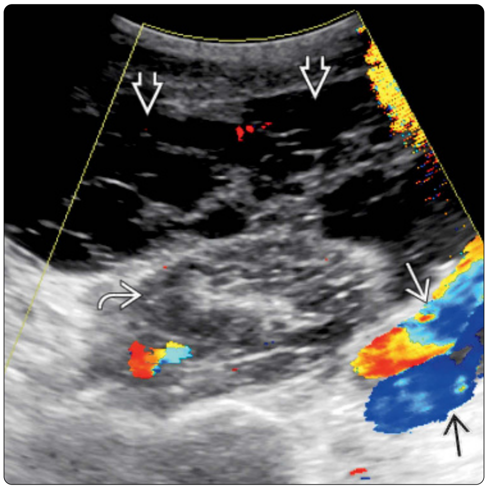


US-Guided Trocar Drain Placement (Peritransplant Fluid Collection)

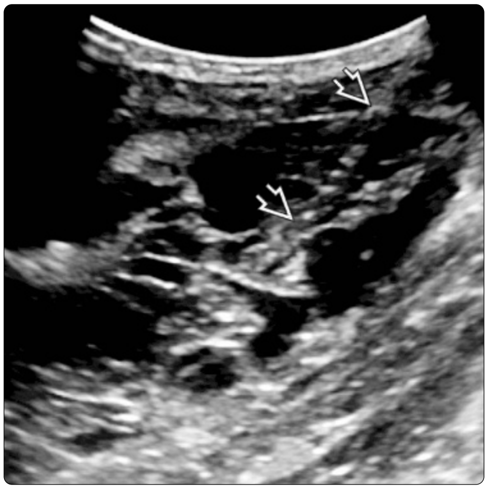


(Left) *Color Doppler US shows the renal transplant ↪ and the more superficial abscess ⇨. The iliac artery ➔ and vein ➡ are well seen and are not in the intended route of drainage.* **(Right)** *10-Fr pigtail catheter loaded onto a sharp trocar ⇨ is advanced under real-time US into the perirenal collection. When the tip is visualized within the collection, the catheter is unscrewed from the trocar and advanced into the abscess.*

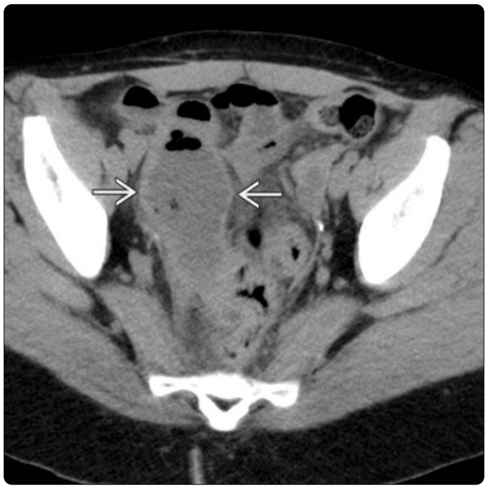
US-Guided Trocar Drain Placement (Prospective Drainage Route)



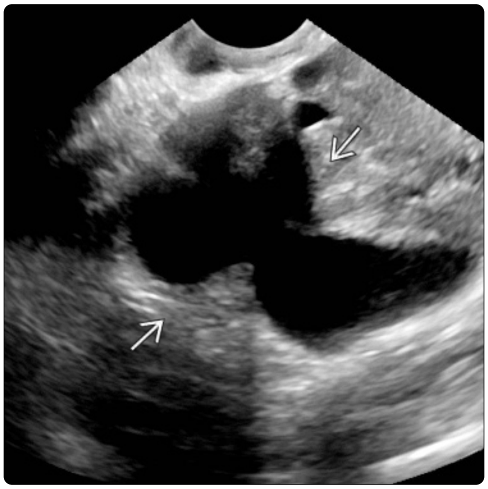
US-Guided Trocar Drain Placement (Catheter/Trocar Introduction)



Transvaginal Drainage (Initial CT)

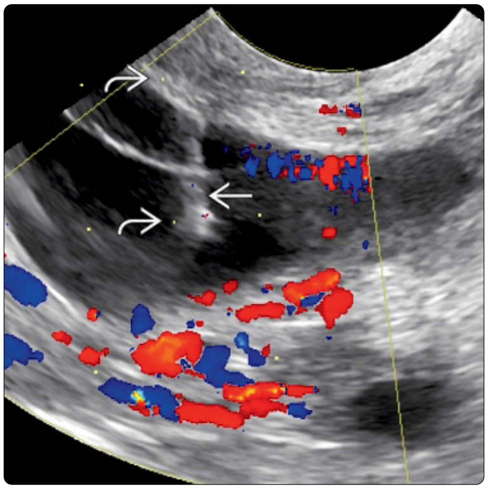


Transvaginal Drainage (Preliminary US Evaluation)

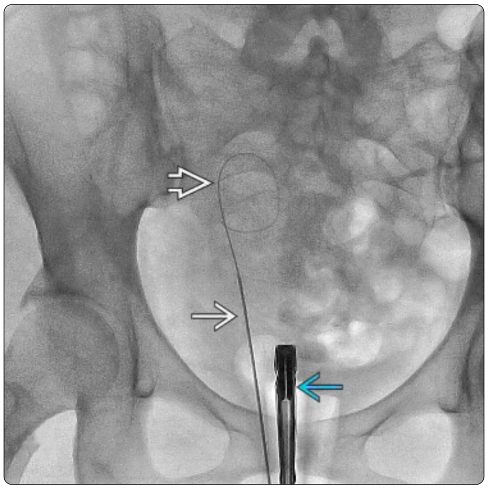


(Left) *This 34-year-old woman presented with fever and pelvic pain. A collection in the pelvis* → *is concerning for tuboovarian abscess.* **(Right)** *A preliminary transvaginal ultrasound (different patient) demonstrates the typical ultrasonographic appearance of a cystic adnexal collection* →.

Transvaginal Drainage (Trocar Needle Introduction)

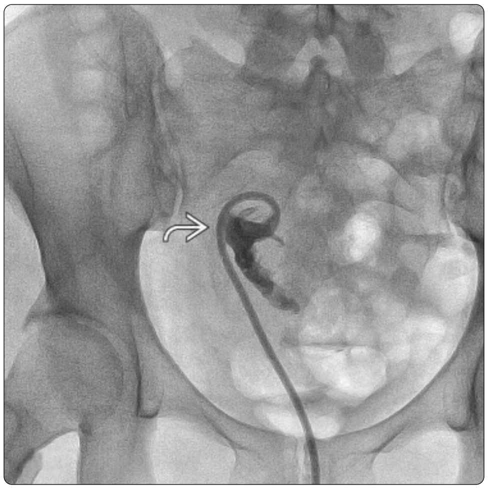


Transvaginal Drainage (Flouroscopic Imaging During Wire Advancement)

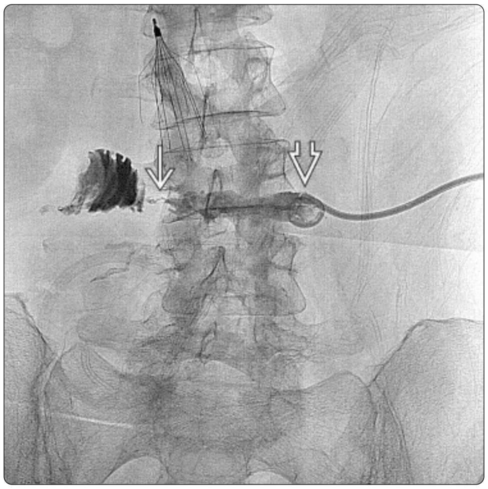


(Left) *Color Doppler US is employed to assess for any intervening vessels that might complicate a transvaginal drainage procedure. A catheter-trocar assembly* → *is seen as it is advanced into the abscess collection. US transducer needle guide markers* ↪ *can help guide the trajectory using real-time US.* **(Right)** *In a different patient, the transvaginal US probe* → *is seen as a wire* ⇨ *is advanced into the collection through the access needle* →.

Transvaginal Drainage (Final Drain Evaluation)



Enterocutaneous Fistula (Drain Evaluation)



(Left) *The tract was dilated and the pigtail drain* ↪ *is advanced over the wire with fluoroscopic guidance. Contrast injection confirms proper location of the drain.* **(Right)** *A drain was placed in this patient with Crohn disease to help control leakage of bowel contents onto the patient's skin. During drain placement, Crohn patients should be informed that fistula can take months to heal (3 months, in this case). This drain* ⇨ *was slowly withdrawn from the fistula* →*, and no suction applied to the collection bag.*

KEY FACTS

PREPROCEDURE

- **Indications**
  - Long-term nutritional support
  - Gastric decompression
  - Gastrojejunostomy (GJ) tube if aspiration, reflux, gastroparesis
- Review prior CT (if available) to assess window

PROCEDURE

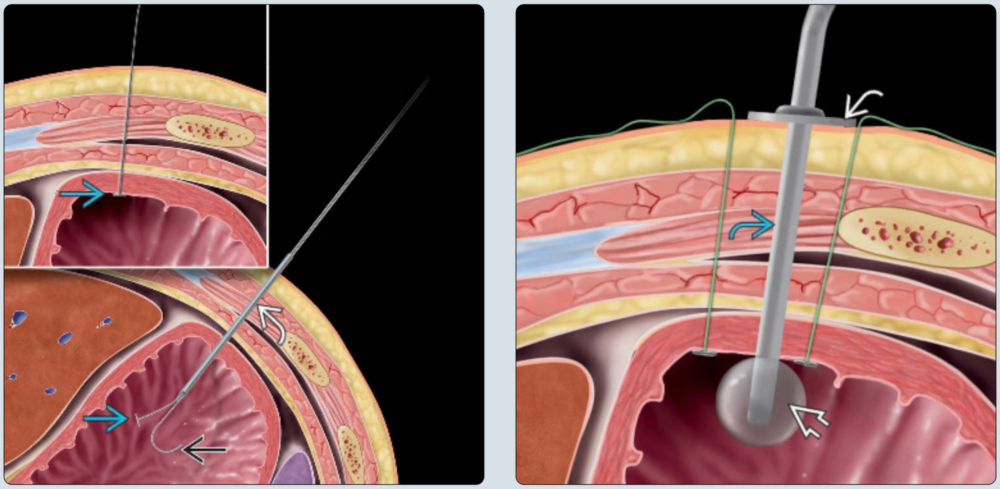
- Localize liver edge and transverse colon
- Insufflate stomach with air via nasogastric (NG) tube
- Optimal tube entry between lesser/greater curvature
  - Avoids large vessels at periphery
- Consider CT guidance if
  - Postoperative stomach
  - No window avoiding liver/bowel/costal margin
  - Inability to place NG tube
- Perform gastropexy to prevent wire buckling
  - Do not secure T-fasteners too tightly
  - May result in pain or skin necrosis
- Aim toward pylorus when inserting needle/tube
  - Facilitates future gastrostomy (G) to GJ tube conversion
- Gastrojejunostomy
  - Use directional catheter to negotiate pylorus

POST PROCEDURE

- Do not use G or GJ tube for 4-12 hours
- Cut T-fasteners in 7-10 days
  - Chronically retained fasteners can become irritant

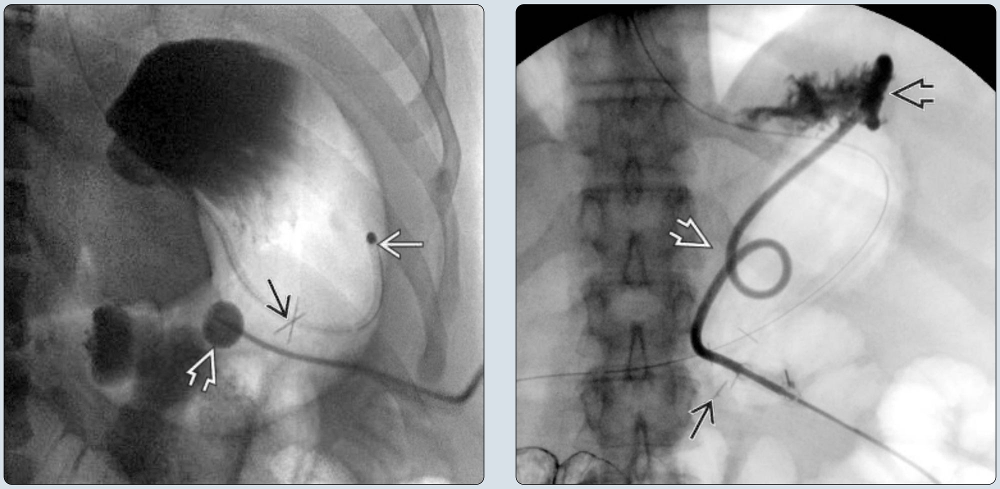
OUTCOMES

- Reported technical success rate: 96-100%
- Complication: Increasing pneumoperitoneum
  - Possible tube dislodgement



Gastropexy **Gastrostomy Tube Placement**

(Left) *A needle ➦ loaded with a T-fastener ⇨ is advanced through the abdominal and gastric walls into the gastric lumen. A wire ⇨ pushes the fastener from the needle into the stomach. Inset shows the secured fastener.* **(Right)** *With T-fasteners securing the gastric wall to the abdominal wall, a gastrostomy tube ➦ is placed percutaneously into the gastric lumen. In this case, the gastrostomy tube is held in place between an intraluminal balloon ⇨ and external disc ➦ adjacent to the skin. T-fastener strings are secured.*



Gastrostomy Tube, Balloon Type **Gastrostomy Tube, Pigtail Type**

(Left) *This percutaneous gastrostomy (G) tube is held in place by the contrast-filled, intraluminal balloon ⇨. The well-distended stomach also contains a nasogastric (NG) tube ➔ used for insufflation and 2 gastropexy T-fasteners ⇨.* **(Right)** *Alternatively, the intraluminal pigtail ⇨ design of this G tube holds it in place. Gastropexy was performed with 4 (often 2-4 per physician preference) T-fasteners ⇨. Contrast injected via the G tube opacifies the dependent gastric fundus ⇨.*

Gastrostomy/Gastrojejunostomy

TERMINOLOGY

Abbreviations

- Gastrostomy (G) tube
- Gastrojejunostomy (GJ) tube
- Jejunostomy (J) tube

Synonyms

- Radiologically implanted gastrostomy
- Percutaneous radiologically guided gastrostomy
- Percutaneous endoscopic gastrostomy (PEG)
  - Radiologically placed tubes without use of endoscope often erroneously referred to as PEG

Definitions

- Gastrostomy: Creation of artificial external opening into stomach
  - May create surgically/endoscopically/percutaneously
  - Used to insert enteral tube terminating in stomach
- Gastrojejunostomy: Creation of artificial external opening into stomach, insertion of enteral tube with end-ports in stomach and jejunum
  - Advantage over gastrostomy of low aspiration risk
  - Disadvantage of potential malposition or bowel obstruction
- Gastropexy: Fixation of anterior stomach to abdominal wall
  - Gastric wall affixed percutaneously for stabilization during G/GJ tube procedures
- Jejunostomy: Creation of artificial external opening into jejunum
  - Does not involve transgastric access
  - Used to directly insert enteral tube into jejunum

PREPROCEDURE

Indications

- Long-term nutritional support
  - Neurologic disorders impairing swallowing
    - Stroke, amyotrophic lateral sclerosis
  - Esophageal malignancy/obstruction
  - Head and neck cancer
- Gastric decompression
- Consider GJ tube if history of
  - Aspiration
  - Gastroesophageal reflux
  - Gastroparesis

Contraindications

- Absolute
  - Lack of safe access to stomach
  - Uncorrectable bleeding diathesis
- Relative
  - Previous gastric surgery
  - Gastric cancer or varices
  - Uncorrected ascites (requires paracentesis/gastropexy)

Preprocedure Imaging

- Review prior abdominal CT scan
  - Assess safe access to stomach
    - Is there colonic interposition?
  - If ascites, consider preprocedure paracentesis
- If no prior CT, unnecessary before procedure unless
  - Prior history of esophageal or gastric surgery
  - Suspected/known peritoneal disease
  - Known portal hypertension
    - Assess for possible gastric varices

Getting Started

- Things to check
  - Pertinent clinical history and physical examination
    - Current medications
      - Any anticoagulant or antiplatelet agents
    - History of aspiration or gastroesophageal reflux
      - May prompt GJ tube rather than G tube placement
  - **Hemostatic risk**
    - Initial placement: Moderate risk of bleeding
    - Platelet count: Not routinely recommended
      - Transfusion recommended if known < 50,000/μL
    - International normalized ratio recommended
      - Correct to < 1.5
    - Activated partial thromboplastin time if receiving IV heparin
      - Correct if > 1.5x control
    - Clopidogrel: Hold 5 days prior to procedure
    - Aspirin: Do not hold
    - Over-wire replacement: Low risk of bleeding
  - No oral intake for 12 hours prior to procedure
  - **Consent**
    - Include complications of bleeding, aspiration pneumonia, injury to internal organs (i.e., liver, pancreas, bowel), peritoneal irritation, tube dislodgement, and buried bumper syndrome (in tubes with internal bumper)
- Medications
  - **Anesthesia**
    - 1% lidocaine local anesthetic
    - Use procedural sedation if possible
      - Fentanyl, midazolam typically used
    - Anesthesiology assistance may be required if
      - Airway management issues, cardiac function issues, neurologic disorders, combative/disoriented/demented patient
  - **Prophylactic antibiotics**
    - Potential organisms: *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Corynebacterium* spp.
    - Procedure classification: Clean-contaminated
    - Society of Interventional Radiology Practice guidelines
      - Is routine prophylaxis recommended?
      - Yes, during "pull" PEG placement, which traverses oropharynx
      - No consensus with percutaneous "push" technique
      - Cefazolin 1 g IV 1st-choice antibiotic
    - Head and neck cancer patients
      - Some reports indicate reduced incidence of skin site infection
      - Preprocedure: 1 g cefazolin IV
      - Postprocedure: 500 mg cephalexin orally or via G tube 2x daily for 5 days
      - Clindamycin if cephalosporin allergy
  - **Gastric motility**
    - 1 mg glucagon IV reduces peristalsis
    - Air remains in stomach, limits passage through pylorus

    - Avoid in GJ tube placement; may impede jejunal catheterization
    - Contraindications
      - Pheochromocytoma, insulinoma
      - Insulin-dependent diabetes mellitus
- Equipment list
  - **General**
    - Fluoroscopy equipment
      - Primary modality for imaging guidance
    - CT equipment
      - Use if difficult access to stomach anticipated on preprocedure imaging
      - Radiopaque grid for localizing point of access
    - US equipment (to mark liver edge)
      - 3- to 5-MHz transducer
    - Nasogastric (NG) tube, 5-Fr catheter will work
    - Insufflator bulb device, 60-cc syringe with 3-way
    - #11 scalpel blade
    - Dilators and peel-away sheath
  - **Gastropexy**
    - T-fasteners (2-4) and 18-gauge slotted needle
    - 10-mL syringe (50:50 air:saline)
    - 0.035" Amplatz wire
  - **Gastrostomy**
    - Various configurations commercially available
      - Retention pigtail type
      - Retention balloon type
      - Retention mushroom type (bumper type): Most durable, transoropharyngeal placement
      - Low profile: Small hub with valve at skin, easily hidden under clothing (active patient, children), size specific based on tract distance
  - **Gastrojejunostomy**
    - Various configurations commercially available
      - Retention pigtail type
      - Retention balloon type
      - Double-lumen type with jejunal feeding port and gastric decompression port
    - Directional 5-Fr catheter (e.g., Kumpe)
    - Guidewires; type dependent on difficulty of negotiating pylorus
      - Amplatz, J-tip, angled hydrophilic

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Patient supine; anterior percutaneous approach
  - With pen, mark line on skin along edge of liver as visualized with US
    - Prevents inadvertent hepatic traversal
  - Preliminary fluoroscopy to localize transverse colon
  - Alternatively, assess if colonic position discernible by intraluminal air
    - If not discernible, administer enema using air-/water-soluble contrast/barium

Equipment Preparation

- If no NG tube in place
  - Insert 5-French catheter (e.g., Kumpe) over J-tip wire; use as NG tube
  - Esophageal catheterization may be facilitated with lateral fluoroscopy
- Load T-fastener onto 18-gauge slotted needle
  - Attach 10-mL syringe containing 3-5 mL saline
  - Various available T-fasteners operate differently
    - Be familiar with operation of chosen T-fasteners

Procedure Steps

- **General**
  - Cleanse skin with preparatory solution
  - Sterilely drape access site to isolate sterile field
  - Establish access window to stomach
    - Place clamp on skin line marked by US as edge of liver; confirm clamp position fluoroscopically
    - Administer 1 mg glucagon, if no contraindication
    - Insufflate stomach with air via NG tube
      - AP view: Stomach completely displaces transverse colon
      - Lateral view: Stomach abuts anterior abdominal wall
    - Select gastrostomy site
      - Optimal placement midway between lesser and greater curvature
      - Junction of gastric body and antrum ideal
      - Entry site generally should be below liver edge/above transverse colon
      - Avoid intercostal access (painful)
      - Avoid peripheral placement near lesser or greater curvature (avoids large vessels)
  - Consider CT guidance if
    - Postoperative stomach
    - No access window that avoids liver, bowel, and costal margin
    - Inability to place NG tube
- **Gastropexy**
  - Secures anterior wall of stomach
    - Prevents movement of gastric wall; buckling of guidewire during tract dilatation
    - Some operators do not routinely perform gastropexy for G tube placement
      - However, one study shows reduced risk of initial intraperitoneal tube placement
      - If no gastropexy, continuous air insufflation may be necessary to keep stomach distended
      - Recommended in patients with high chance of leakage
    - May improve probability of tube rescue if dislodged in first 1-2 weeks before tract matures
  - Determine site of T-fasteners (2-4), administer 1% lidocaine, make skin nick with #11 scalpel
  - Create 2-cm square or triangle skin area that will serve as gastrostomy access window
    - Advance needle loaded with T-fastener into skin while suctioning with syringe
      - Observe AP and lateral intermittently
      - Entry into stomach confirmed when air aspirated into syringe
    - Once air aspirated, disconnect syringe from needle
      - Slowly inject contrast through needle with lateral fluoroscopic visualization
      - Watch contrast drip into gastric lumen

      - Ensure contrast not pooling anterior/posterior to gastric lumen
      - Advance 0.035" Amplatz guidewire through needle to release T-fastener
    - Advance wire until deflects off at least 3 walls of stomach
      - Confirms wire in stomach, not intraperitoneal
      - Confirms T-fastener released into stomach
    - Repeat to deploy additional T-fasteners
      - Check degree of gastric distension prior to each T-fastener placement; insufflate as necessary
    - Apply gentle traction to retention sutures of each T-fastener
      - Approximates gastric/anterior abdominal walls
    - Lock T-fasteners in place to secure gastropexy
      - Many fasteners lock by crimping metallic cuff
      - Do not fasten too tightly (e.g., skin indents) as it is painful and there is potential for skin necrosis
  - 1 anchor gastropexy technique recently reported
    - Anchor dislodgements relatively common; major complications associated (e.g., peritonitis/bleeding)
- **G tube**
  - Administer 1% lidocaine local anesthetic at center of gastropexy
  - Nick skin with #11 scalpel blade
  - Bluntly dissect with clamp
  - Fill 10-mL syringe with 3-5 mL sterile saline; attach to 18-gauge needle
  - Check gastric distension with fluoroscopy
    - Insufflate as necessary
  - Advance needle into stomach while applying suction to syringe
    - Aim slightly toward pylorus
      - Will facilitate future G to GJ tube conversion, if necessary
    - Needle is in stomach once air is aspirated
    - Drip contrast in gastric lumen with lateral fluoroscopic visualization
  - Advance Amplatz wire into stomach
  - Dilate tract to size as appropriate for selected gastrostomy catheter
  - Advance peel-away sheath
  - Advance G tube in stomach
  - Remove wire
  - Activate retention mechanism
    - Lock pigtail for pigtail-type G tube
    - Fill balloon with water if balloon-tipped G tube
  - Inject contrast into G tube; confirm position in stomach
  - Do not use G tube for 12-24 hours if it is for feeding
    - Newer studies support feeding after 4-6 hours
  - Attach to gravity drainage bag if for gastric decompression
- **GJ tube**
  - Follow first 5 steps of G tube placement
  - Advance needle into stomach while applying suction to syringe
    - Needle is in stomach once air is aspirated
    - Very important to aim needle toward pylorus
    - Aspirate air, inject contrast to confirm intraluminal access
  - Advance nonhydrophilic wire into stomach
  - Advance directional catheter (e.g., Kumpe) over guidewire into stomach
  - Use combination of guidewire/directional catheter to cross pylorus
    - Consider use of hydrophilic wire or other directional catheter (e.g., Cobra/Kumpe) if difficult access
    - Inject contrast through catheter if necessary to visualize pylorus
    - Sheath placement into stomach may aid in pyloric catheterization
  - Once negotiated through pylorus, advance catheter and guidewire past ligament of Treitz into jejunum
  - Exchange guidewire for Amplatz guidewire
  - Dilate tract into stomach as appropriate for selected GJ tube
  - Insert peel-away sheath into stomach over wire
  - Advance GJ tube over guidewire until tip is in jejunum
  - Remove wire and peel-away sheath
  - Inject contrast into GJ tube to confirm position
  - Activate retention mechanism
    - Lock pigtail for pigtail-type GJ tube
    - Fill balloon with water if balloon-retention system
- **Dislodged/malfunctioning G/GJ tube replacement**
  - **Dislodged tube replacement**
    - Ideally should reinsert via previously created tract
      - Tract may close if reinsertion not performed relatively soon after dislodgement
    - Use catheter/hydrophilic guidewire to probe tract
      - Introduce hydrophilic guidewire into stomach
      - Advance 5-Fr catheter over guidewire
      - Remove hydrophilic guidewire; inject contrast to confirm catheter in stomach
    - If G tube replacement
      - After confirming catheter intragastric, introduce stiff guidewire (e.g., Amplatz) via catheter
      - Remove catheter; advance new G tube over wire
      - Confirm tube position with contrast injection
      - Secure G tube
    - If GJ tube replacement
      - After confirming catheter intragastric, use directional catheter/guidewire to cross pylorus
      - After crossing pylorus, advance catheter/wire past ligament of Treitz into jejunum
      - Exchange for Amplatz guidewire
      - Advance GJ tube over wire until tip is in jejunum
      - Inject contrast via GJ tube to confirm position
      - Secure GJ tube
    - If original tract cannot be successfully negotiated, may require creation of new gastrostomy
  - **Malfunctioning tube replacement**
    - Introduce guidewire through malfunctioning tube
      - Advance guidewire beyond tube tip
    - Hydrophilic guidewire may be easier to advance than nonhydrophilic guidewire
      - Solidified secretions/feedings in tube
    - Remove tube over guidewire; leave wire in place
    - If hydrophilic wire used, advance 5-Fr catheter over guidewire into stomach/jejunum
      - Exchange for stiff guidewire (e.g., Amplatz)

- Remove catheter from guidewire
- Advance new G/GJ tube over guidewire
- Remove guidewire
- Confirm tip position with contrast injection
- Secure G/GJ tube

- **CT-guided G/GJ tube**
  - Indications for CT guidance
    - Poor access to stomach
    - Postoperative stomach (e.g., accessing excluded segment in gastric bypass patient)
    - Inability to place NG tube
  - CT-guided gastrostomy placement
    - Place radiopaque grid on skin; obtain CT images
      - Insufflate air through NG tube if in place
    - Mark skin entry site for gastropexy T-fasteners (2-4)
    - Cleanse skin with preparatory solution
    - Sterilely drape skin; isolate sterile field
    - Administer 1% lidocaine local anesthetic
    - Repeat air insufflation of stomach if necessary
    - Advance T-fastener using fluoroscopy
      - Check position of guidewire with CT
    - If no NG tube in place or inserting into excluded gastric segment
      - Advance 22-gauge needle into stomach
      - Obtain CT images to check position
      - Administer contrast via needle; repeat CT scan if stomach collapsed
      - Confirm intraluminal needle position
    - Secure T-fasteners into position
    - Administer 1% lidocaine at center of gastropexy
    - Nick skin with #11 blade
    - Bluntly dissect with clamp
    - Advance needle while suctioning saline-filled syringe
      - Aim needle toward pylorus
    - Once air aspirated, remove syringe; advance wire
    - CT to confirm guidewire in stomach
    - Measure skin to stomach distance along guidewire
    - Dilate tract
      - Sequentially introduce larger dilators
    - Advance peel-away sheath
    - Advance G tube over guidewire into stomach
    - Remove peel-away sheath/guidewire
    - Lock retaining mechanism for G tube
    - Obtain CT images to confirm position
- **J tubes**
  - New placement
    - Difficult: Jejunum is highly mobile, easily collapsed
      - Advanced 5-Fr nasojejunal (NJ) catheter
      - Jejunum dilated with saline slowly
      - Percutaneous access achieved with fluoro/US/CT
      - 1 anchor gastropexy suggested
      - Dilate, advance J tube, confirm location with contrast
      - Inflate balloon (if applicable) with 3-5 cc saline; overinflated balloon can occlude jejunal contents
    - Percutaneous radiologic jejunostomy placement successful 85%
    - Direct percutaneous endoscopic placement successful 72-88%
  - Replacement
    - Over-wire replacement performed with fluoroscopy
    - Inject contrast through existing J tube to outline bowel
    - Advance guidewire through J tube (if tube clogged, run wire through 4- to 6-Fr dilator alongside J tube within tract)
    - Deflate J-tube balloon (if applicable)
    - Remove J tube over guidewire (hydrophilic)
    - Cut new J tube to length of old J tube (as needed)
    - Advance new J tube over wire
    - Inflate balloon (if applicable) with 3-5 cc saline; overinflated balloon can occlude jejunal contents

Findings and Reporting

- Report number of T-fasteners placed
  - Indicate that T-fasteners should be cut 7-10 days after placement
- Describe position of tip of tube
- Postprocedure orders
  - No alimentation via new G/GJ tube for ~ 12-24 hours
    - Newer studies indicates it is safe after 4-6 hours
  - Increase tube feedings slowly
    - Avoids gastric overdistension; hyperperistalsis
  - Consider tube replacement per manufacturer recommendations
    - Prevent tube malfunction

Alternative Procedures/Therapies

- Radiologic
  - Percutaneous button-type gastrostomy
    - May have buried bumper syndrome with this tube
      - Internal bumper migrates into gastrostomy tract; becomes overgrown by gastric mucosa
      - Avoided by regular checking of tube position, leaving small distance between external bumper and skin and daily rotation of tube
- Surgical
  - Open or laparoscopic gastrostomy/jejunostomy
    - Less used than radiologic/endoscopic placement
- Endoscopic
  - PEG
    - May be difficult in postoperative stomach
    - Increased skin infection rate due to passage of G tube through oropharynx, thus exposing tube and gastrostomy tract to oral flora
    - Increased rate of gastrostomy tract seeding with tumor in patients with upper GI tract or ear/nose/throat cancers

POST PROCEDURE

Continuous Care/Maintenance

- Clean daily with mild soap and water, avoid harsher agents
- If leaking at skin, ensure bolster is snug to skin
- Treat excessive granulation tissue with topical silver nitrate or high-potency topical steroid
  - May need to trim tissue with surgical scissors to reduce irritation and decrease drainage
- Unclogging enteral tube
  - Flushing with 50 mL of warm water opens tube 1/3 of time
  - Installation of pancreatic enzymes if flushing fails

  - Use mechanical devices, such as Fogarty balloon or biopsy brush
- Routine tube replacement intervals vary but usually are 3-6 months
- Flush before and after each feeding or medication administration

Things to Do

- Do not use G or GJ tube for 4-12 hours
- Cut T-fasteners in 10-14 days
- Flush tube routinely to prevent clogging

Things to Avoid

- Do not secure T-fasteners too tight
  - May result in pain or skin necrosis
- Avoid tube placement along periphery of stomach
  - Increases bleeding risk; vessels larger along periphery
- Avoid dressing between skin and bolster
  - Persistently wet dressings hasten skin breakdown
- Avoid administering pills through tube

OUTCOMES

Problems

- Difficulty negotiating guidewire/catheter through pylorus for GJ tube placement
  - Reglan 10 mg IV to stimulate bowel motility
  - Hydrophilic guidewire passes more easily
  - May consider G tube placement
    - Later conversion to GJ tube
- Postprocedure pain at gastropexy site
  - T-fasteners may be too tight
    - Consider cutting T-fastener early
      - One study showed cutting at day 2 without complications
    - Preferable to have at least 2 T-fasteners remain in place for 10-14 days
  - Abdominal wall hematoma
    - Provide analgesics for pain control
    - Hold anticoagulant/antiplatelet agents until resolved, if possible
  - Abdominal wall infection
- Tube malfunction/dislodgement
- Hemorrhage from tube
  - Small amounts of blood products immediately after procedure can be managed expectantly
  - If there is persistent or severe bleeding, consider
    - Endoscopy to verify source
    - Angiography, with embolization if appropriate
      - Angiography should be performed with G tube removed over guidewire
      - Indwelling tube may tamponade bleed, impeding angiographic visualization
- Double-lumen gastrojejunostomy
  - Use for patients needing gastric decompression as well as enteral nutrition
  - Gastric port sideholes for decompression; positioned in anterior aspect of stomach
  - May not drain stomach adequately
    - Fundus located posteriorly; dependent accumulation of fluid/debris

Complications

- Most feared complication(s)
  - Leakage with peritonitis
    - Causes
      - Leakage around puncture site
      - Tube migration/erosion causing frank gastric perforation; resultant peritonitis
  - Visceral/enteric transgression by tube
  - Unrecognized placement of tube into peritoneal cavity rather than into stomach/jejunum
- Immediate/periprocedural complication(s)
  - Hemorrhage (1-3% incidence)
  - Pain
  - Peritonitis
- Delayed complication(s)
  - Hemorrhage (tube may have tamponaded bleeding)
  - Skin site infection
- Other complications
  - Pneumoperitoneum
    - Radiographs may identify pneumoperitoneum for several days after procedure
    - Consider CT if increasing in volume &/or associated with symptoms; possible causes
      - Enteric transgression
      - Tube dislodgement
  - Aspiration with G tube feeding
    - Consider converting G tube to GJ tube
      - Much lower aspiration risk with GJ tube
  - Potential for small bowel obstruction with G tube
- Complications from removal
  - Gastrocutaneous fistula
    - Generally closes within few days of removal
    - Various approaches to promote closure include acid suppression therapy, silver nitrate ablation of tract lining, argon plasma coagulation, fibrin glue, endoclipping and endoscopic banding

Expected Outcomes

- Reported technical success rate: 96-100%
- Reported 30-day all-cause mortality: 4-8%
  - Related to underlying illness rather than procedure

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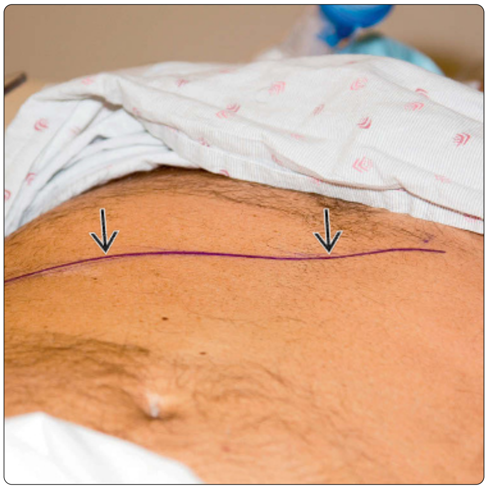
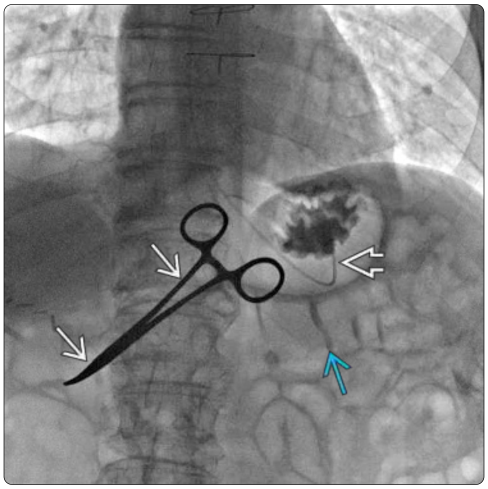
(Left) *Prior to sterile prep, cross-sectional imaging is reviewed to understand the stomach's position in relation to the transverse colon and left hepatic lobe. Once the patient is on the table, US localization of the liver edge is performed and marked →.* **(Right)** *Hemostats overlying the pen mark → show the liver edge. A 5-Fr nasogastric (NG) catheter ⇨ is positioned within the partially distended stomach, and the transverse colon → is currently within the operative field.*

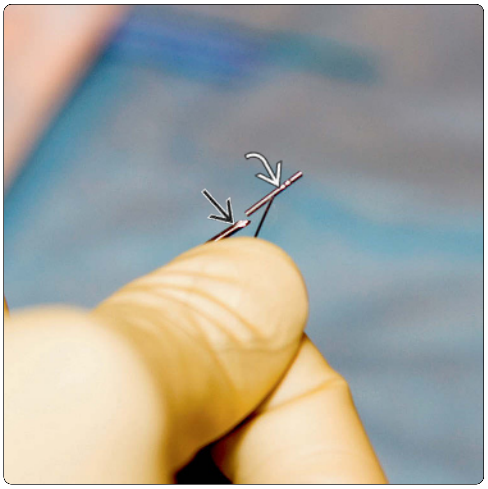


Gastrostomy Tube Placement (Marking Liver Edge)

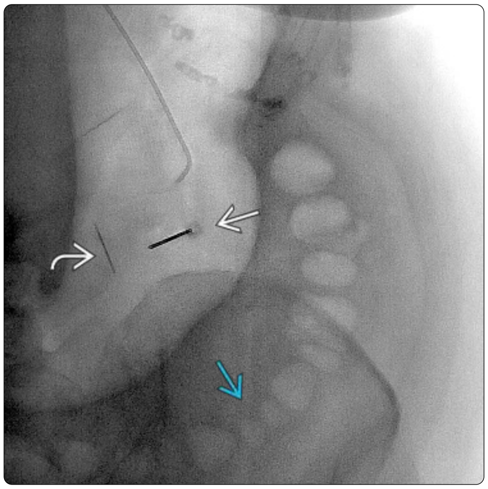


Gastrostomy Tube Placement (Marking Liver Edge)

(Left) *Intraprocedural photograph shows that a T-fastener ↪ is being loaded onto the slot of an 18-gauge needle →. T-fasteners are semiflexible, metallic devices that are not absorbable, and if not released, can become an irritant imbedded within the gastric wall.* **(Right)** *After delivering 0.5-1.0 mg IV glucagon to halt peristalsis in a nondiabetic patient, 360 cc of air insufflated into the stomach via the NG catheter distends the stomach, which displaces the colon →. One T-fastener has been deployed ↪ via the 18-gauge needle →.*

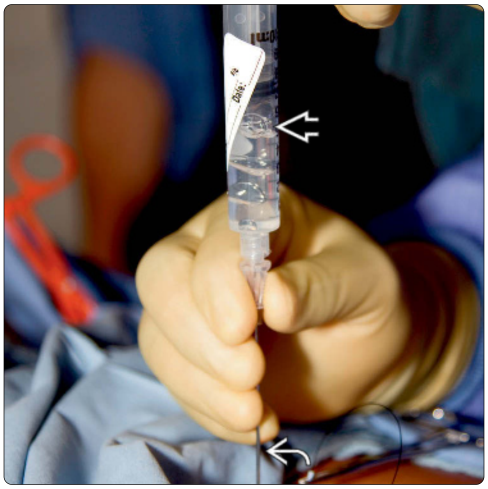


Gastrostomy Tube Placement (Gastropexy Procedure)

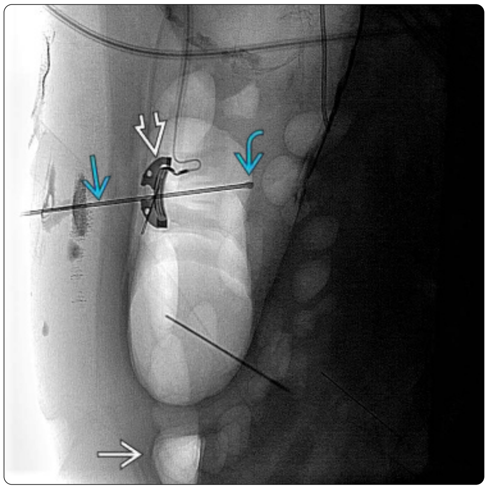


Gastrostomy Tube Placement (Gastropexy Procedure)

(Left) *The 2nd T-fastener is loaded onto a needle ↪, which is advanced into the stomach. With a saline-filled syringe, aspirate through the needle while advancing. Angle slightly toward the pylorus. Needle entry into the stomach is confirmed when air ⇨ is aspirated into the syringe.* **(Right)** *Lateral fluoroscopic imaging is imperative to define needle → depth and to look for colonic gas ⇨ between the skin and stomach. Contrast slowly injected through an intraluminal needle will drip ↪. The EKG lead → was moved.*



Gastrostomy Tube Placement (Gastropexy Procedure)



Gastrostomy Tube Placement (Gastropexy Procedure)

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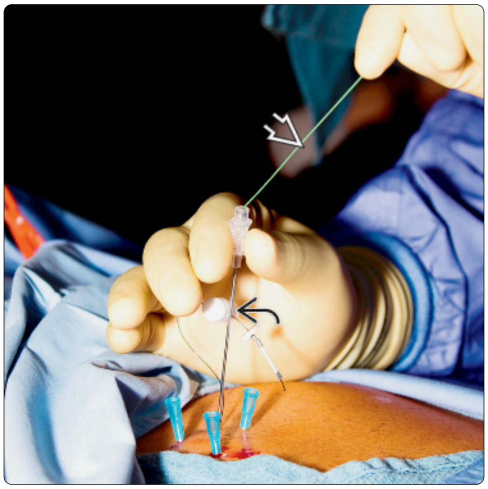
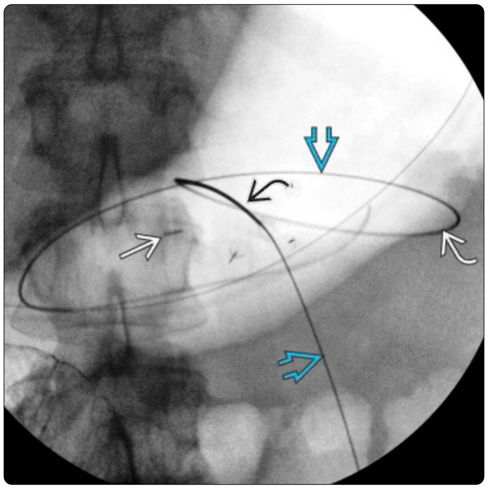
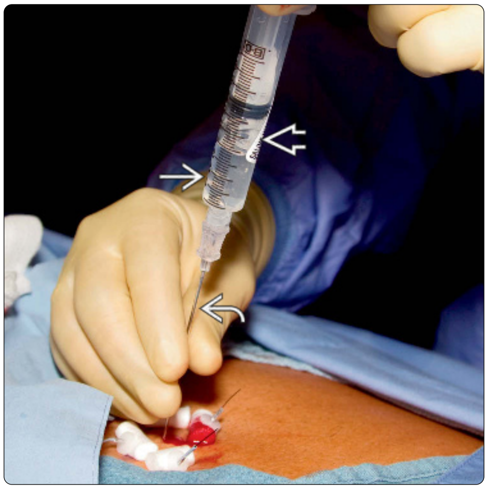


Gastrostomy Tube Placement (Gastropexy Procedure)

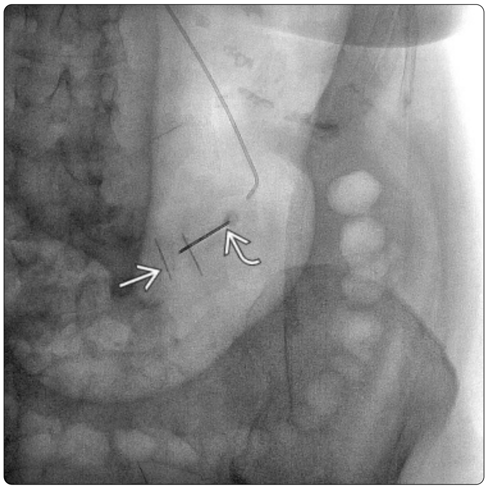


(Left) *With needle tip position confirmed, the syringe is detached and a guidewire ⇨ is advanced through the needle ↪ to deploy the T-fastener into the stomach.* **(Right)** *Corresponding fluoroscopic spot radiograph demonstrates the guidewire ⇨ that has been advanced through the needle ↪ to deploy the T-fastener →. A wire that bounces off of at least 3 walls ↪ of the stomach confirms an intraluminal, rather than an intraperitoneal, location. Lateral imaging will help confirm wire location.*

Gastrostomy Tube Placement (Needle Access Into Stomach)

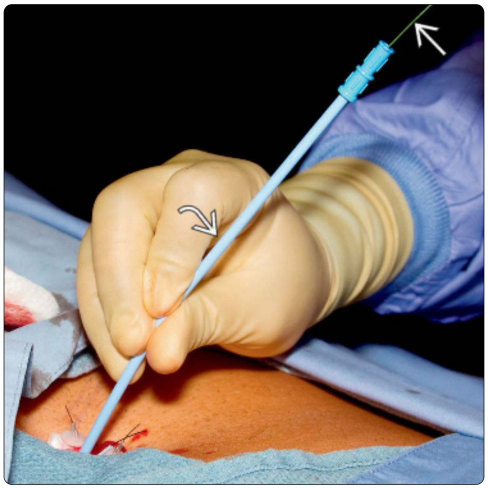


Gastrostomy Tube Placement (Needle Access Into Stomach)

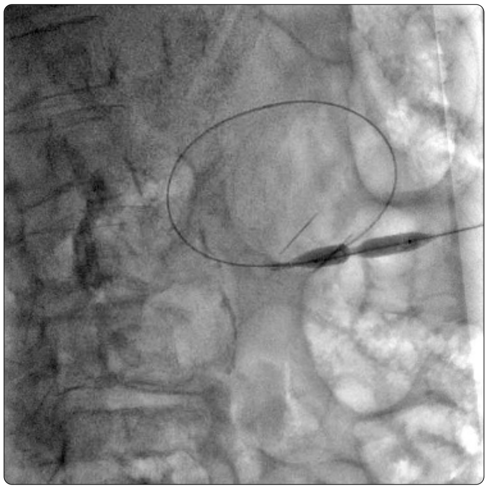


(Left) *With 2-4 T-fasteners in place, a needle ↪ attached to a saline-filled syringe → is inserted into the anesthetized insertion site central to the T-fasteners with a rightward trajectory toward the pylorus. Aspiration of air ⇨, or lateral imaging with contrast drip, confirms intraluminal location.* **(Right)** *Fluoroscopically, the access needle ↪ is seen at the center of the gastropexy T-fasteners →, directed toward the pylorus. Once the needle tip location is confirmed, a stiff 0.035" wire will be advanced into the stomach lumen.*

Gastrostomy Tube Placement (Tract Dilatation)



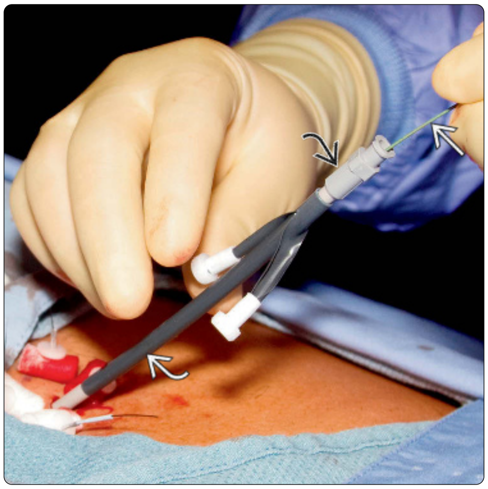
Gastrostomy Tube Placement (Tract Dilation)



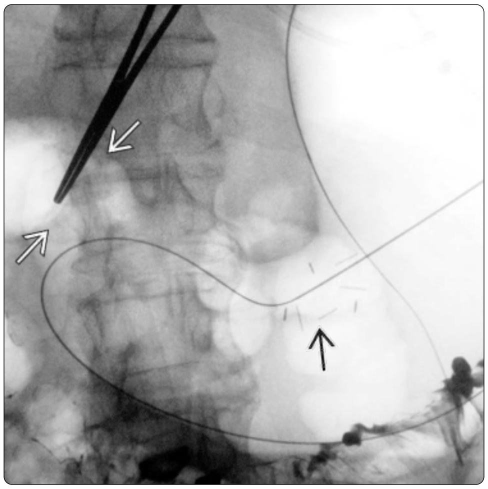
(Left) *The needle has been removed and a dilator ↪ is being advanced over the guidewire →. Sequentially larger dilators will prepare a sufficiently large gastrostomy tract to permit introduction of the G tube. Carefully visualize dilators tracking over the wire: The aorta is just posterior to the stomach, often along the dilator's trajectory.* **(Right)** *Percutaneous tract dilation can be performed with an angioplasty balloon in certain situations (e.g., small stomach, limited wire purchase) but is more costly.*

(Left) *Following sequential dilatation of the G tract, a peel-away sheath ➡ mounted on an inner dilator ⇨ is advanced over the guidewire ➡ into the stomach. Further insufflation of air via the NG catheter may be necessary at this time.* **(Right)** *Ensure that the sheath is advanced over a wire located central to the gastropexy ⇨ and pointed toward the pylorus ➡ rather than toward the fundus. Access pointed toward the fundus may inhibit potential future conversion of the G tube to a GJ tube.*

Gastrostomy Tube Placement (Peel-Away Sheath)

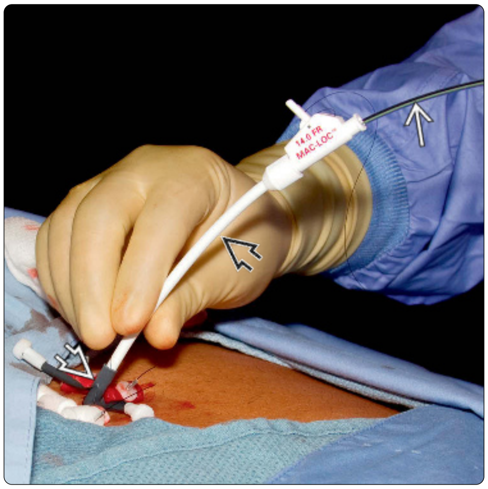


Gastrostomy Tube Placement (Peel-Away Sheath)

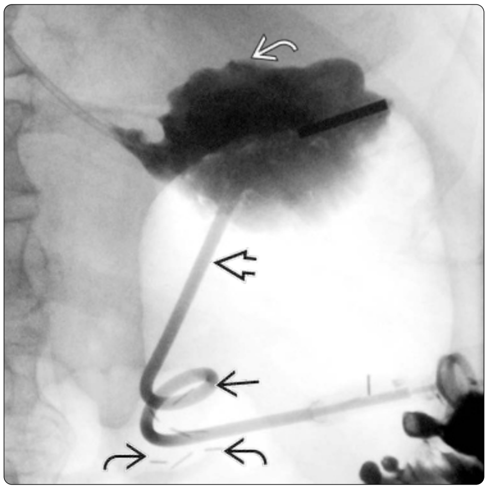


(Left) *The G tube ⇨ is advanced over the indwelling guidewire ➡ through the peel-away sheath ➡ and into the stomach. Placement of a balloon-retention G tube may require a peel-away 2-4 Fr sizes larger than the G tube and may not track over a nonhydrophilic wire.* **(Right)** *Contrast injected into this pigtail-retention G tube ⇨ confirms the final intraluminal position. Contrast ➡ collects within the dependent fundus of the stomach. Note the pigtail retention loop ⇨ adjacent to the gastropexy ⇨.*

Gastrostomy Tube Placement (Pigtail-Type Tube Insertion)

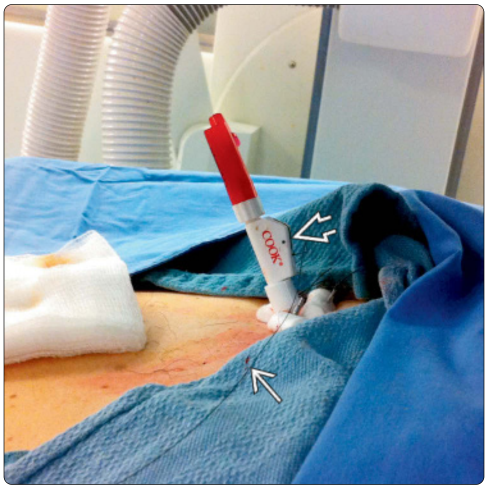


Gastrostomy Tube Placement (Position Confirmation)

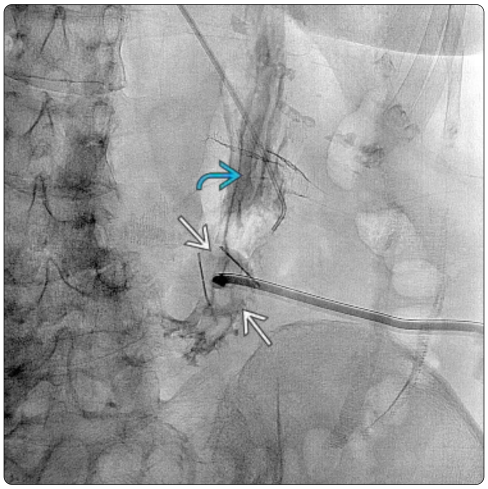


(Left) *In this pigtail-type G tube, the locking suture ➡ is pulled taut, forming the pigtail into a locked position, thereby securing the internal fixation mechanism of the G tube ➡.* **(Right)** *With this balloon-retention G tube, the compliant balloon ➡ is filled with 7-10 cc of sterile water, and the external disc is cinched snug to the skin. Contrast injected through the tube outlines rugal folds ⇨ in the decompressed stomach.*

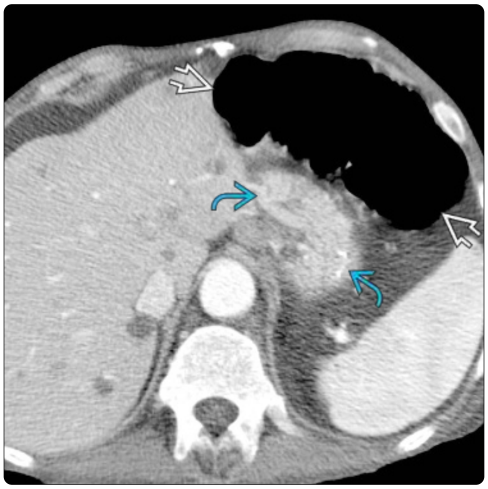
Gastrostomy Tube Placement (Final Tube Position)



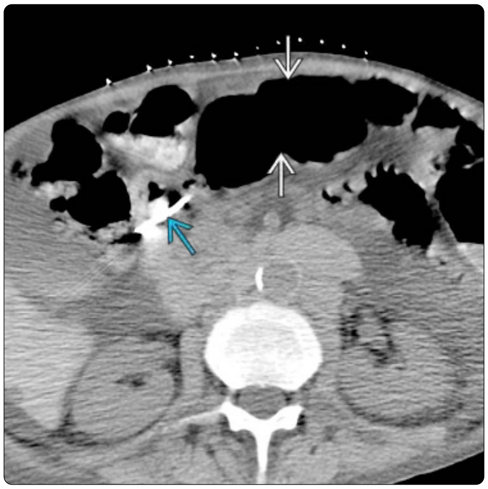
Gastrostomy Tube Placement (Final Tube Position)



CT-Guided Gastrostomy Tube Placement

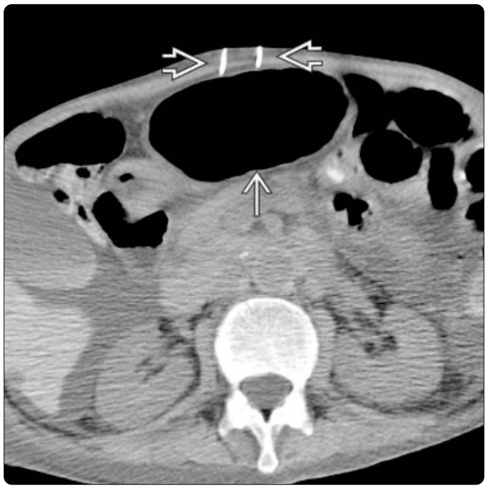


CT-Guided Gastrostomy Tube Placement

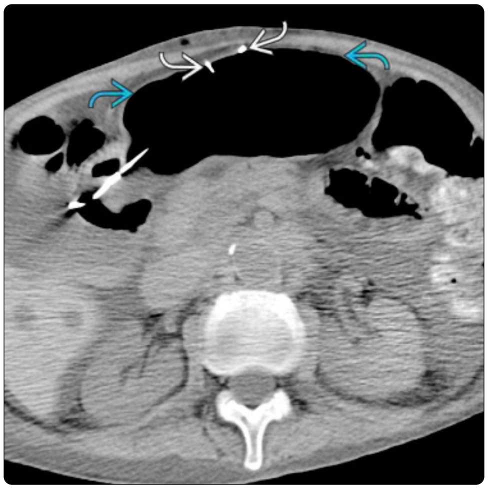


(Left) *Review of a preliminary CT scan obtained to evaluate a request for G tube placement demonstrates the colon ⇨ overlying the collapsed stomach ↪, which indicates a difficult access window to the stomach if performed with fluoroscopic guidance.* **(Right)** *Initial image from CT-guided G tube placement shows an NG tube → in the stomach. A radiopaque grid is placed on the skin over the expected G tube insertion site. The stomach → is distended with air that has been insufflated via the NG tube.*

CT-Guided Gastrostomy Tube Placement

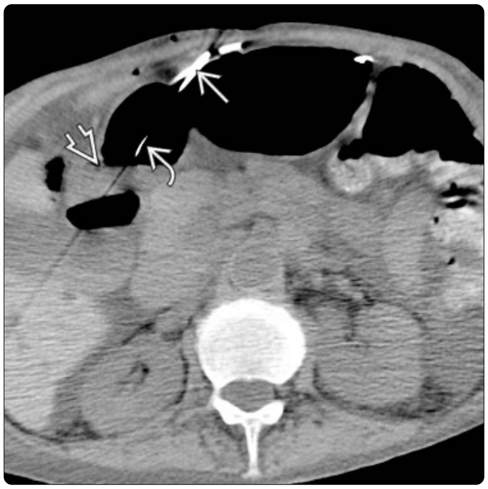


CT-Guided Gastrostomy Tube Placement

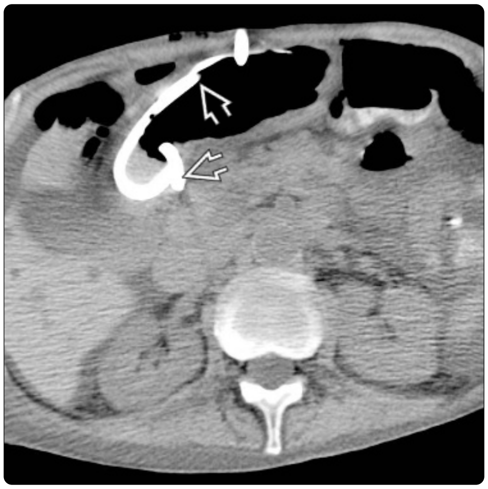


(Left) *Points are selected on the radiopaque grid for the creation of the gastropexy and the skin is marked with a pen. NECT demonstrates 2 needles ⇨ that have been placed in the planned position for the T-fasteners to be introduced into the stomach →.* **(Right)** *Two T-fasteners ↪ are seen securing the anterior gastric wall ↪ against the abdominal wall, thereby forming the gastropexy. It is important to ensure T-fasteners are deployed into the stomach lumen; not positioned within the anterior abdominal wall.*

CT-Guided Gastrostomy Tube Placement



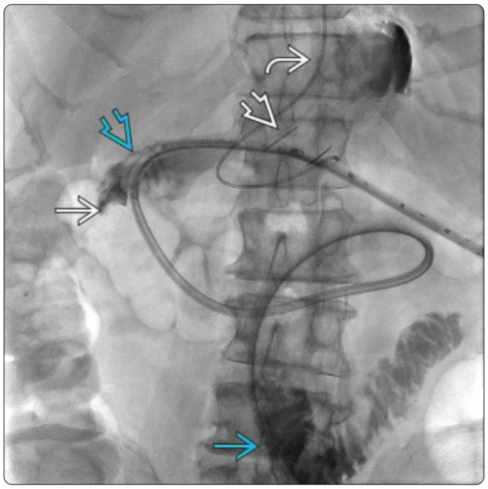
CT-Guided Gastrostomy Tube Placement



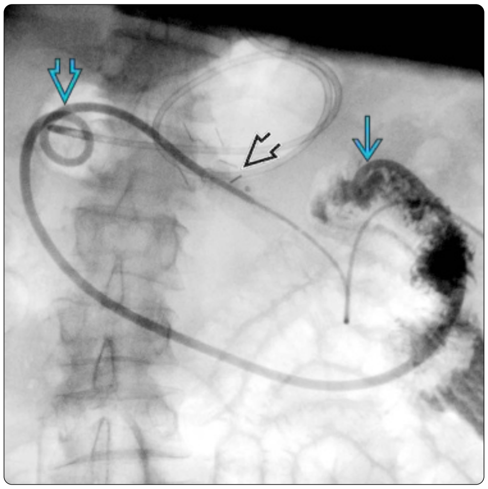
(Left) *After a needle → is introduced through the center of the gastropexy, a guidewire ↪ is advanced through the needle into the stomach and is directed toward the pylorus ⇨. A repeat CT is performed to assess the guidewire position.* **(Right)** *The distance from the skin to the stomach is measured on the CT. The tract is dilated with the dilator advanced over the guidewire by the measured distance. Subsequently, a peel-away sheath is introduced, through which the G tube ⇨ is advanced into the stomach.*

(Left) *After inflating the stomach with air via 5-Fr NG catheter ↪ and placing 2 T-fasteners ⇨, an 18-Fr GJ tube has been advanced over a wire. The GJ tip → is in the jejunum, while the GJ balloon ⇨ has been inflated within the stomach adjacent to the pylorus →. The balloon will now be retracted until it abuts the luminal wall.* **(Right)** *This GJ tube is positioned similarly with the tube passing central to T-fasteners ⇨ and tip in jejunum →. A pigtail ⇨ replaces the balloon, maintaining tube position.*

Gastrojejunal Tube Placement (Balloon-Retention Type)

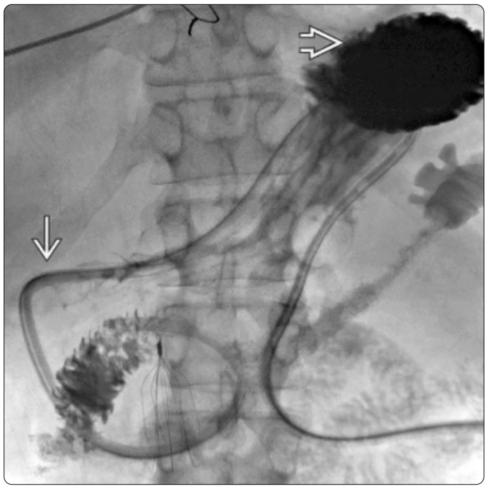


Gastrojejunostomy Tube Placement (Pigtail Retention Type)

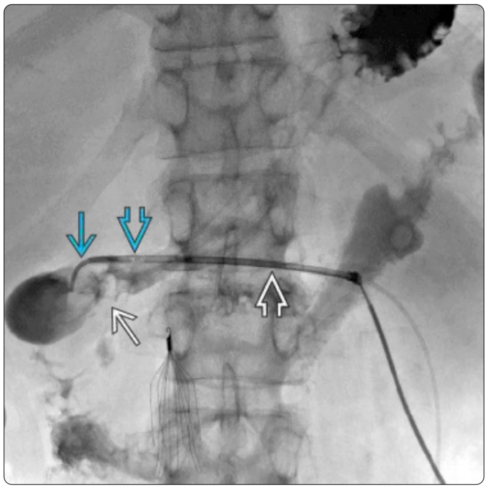


(Left) *Endoscopically placed PEG tubes that are converted to GJ tubes can become looped in the fundus ⇨ since the endoscopic placement angle is often toward the esophagus, not the pylorus →. The GJ maintained this position despite numerous advancements into jejunum.* **(Right)** *The access tract was abandoned. New gastric access ⇨ was obtained through the existing dermatotomy, toward the pylorus →. A 5-Fr angled catheter → was advanced through a 7-Fr guide sheath ⇨.*

Malpositioned Gastrojejunal Tube (Initial Presentation)

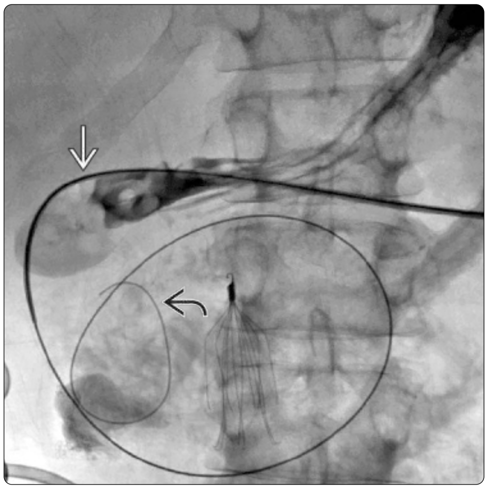


Malpositioned Gastrojejunal Tube (New Access)

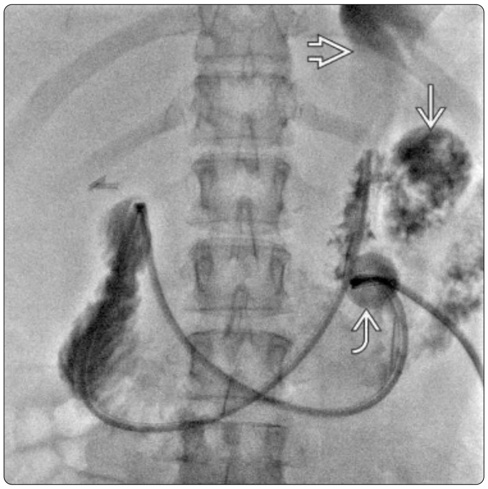


(Left) *A hydrophilic wire and angled catheter were advanced beyond the pylorus → into jejunum ↪. The tract was dilated and a new GJ tube was placed through a peel-away sheath over the wire. No gastropexy was required since the previous GJ resulted in gastric adhesion to the abdominal wall.* **(Right)** *Proper GJ tube position and function are shown in a different patient. Contrast initially injected via G-port flows posteriorly to the dependent fundus ⇨. J-port contrast highlights jejunum →. Note the retention balloon ↪.*

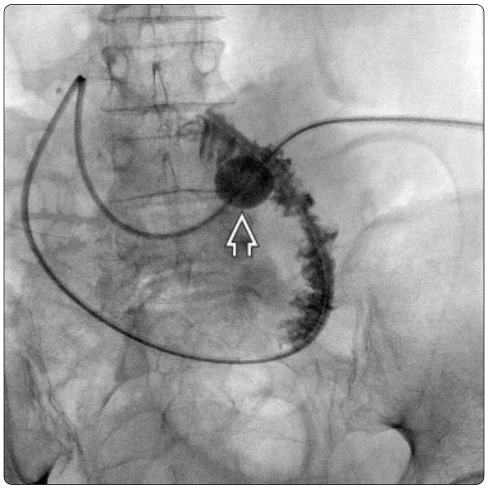
Malpositioned Gastrojejunal Tube (Advancement to Jejunum)



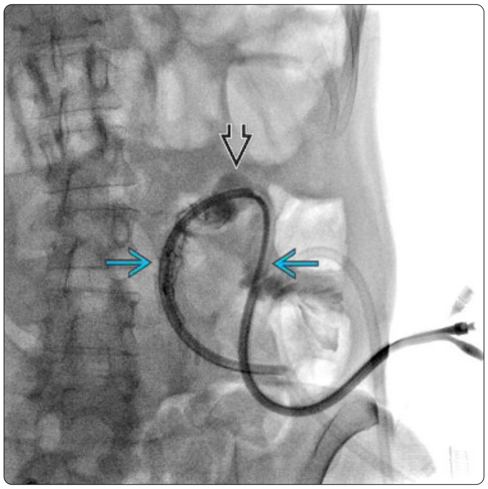
Gastrojejunal Tube (Normal Appearance)



Jejunostomy Tube (Over-The-Wire Exchange)

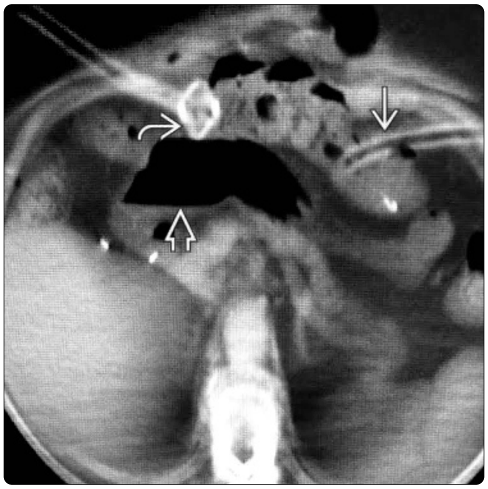


Jejunostomy Tube (Retrograde Replacement)

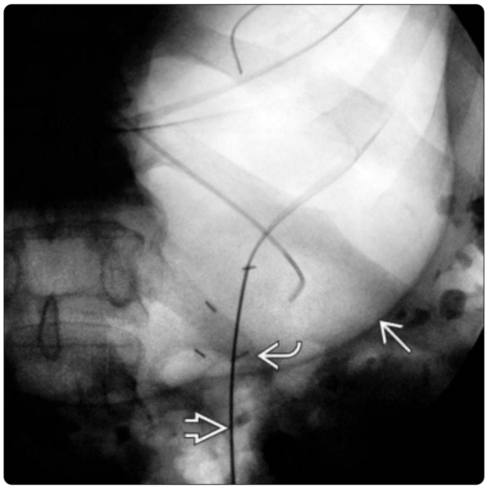


(Left) *After exchanging a jejunostomy tube, inject contrast and observe the direction of peristalsis to insure that the jejunostomy tube is downstream of the balloon. This balloon ⇨ may be slightly overinflated compared to the diameter of the adjacent jejunum.* **(Right)** *Contrast in this case is seen passing on both sides → of the retention balloon ⇨, concerning for retrograde replacement of the jejunostomy tube. Additional obliquities may better define the anatomy.*

Complication (Extraluminal Location of Gastrostomy Tube)

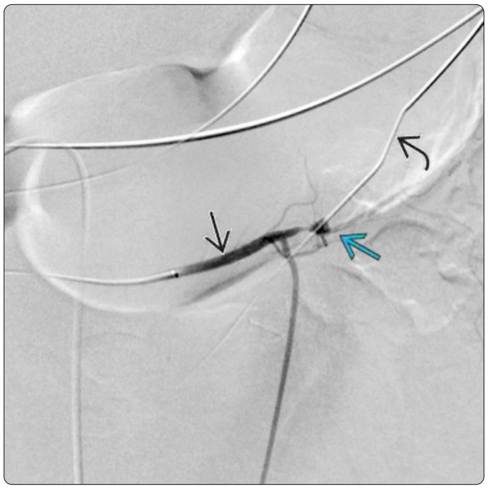


Complication (Hemorrhage via Gastrostomy Tube)

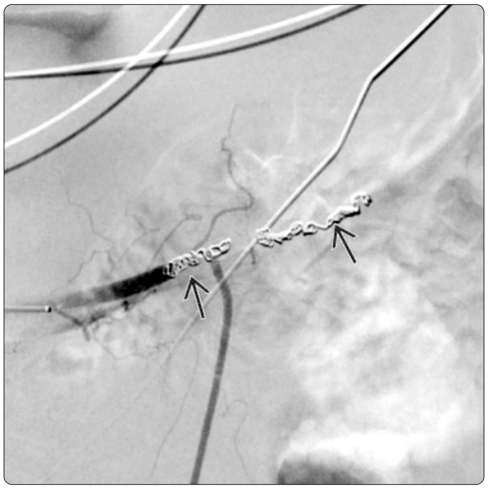


(Left) *A volume-rendered 3D CT image status post gastric bypass demonstrates a malpositioned G tube with the tip ↪ located anterior to the excluded stomach ⇨. A 2nd G tube is partially visualized → in the gastric pouch.* **(Right)** *The gastrostomy tract needle ⇨ and gastropexy T-fasteners ↪ are very near the greater curvature → of the stomach.*

Complication (Hemorrhage via Gastrostomy Tube)



Complication (Hemorrhage via Gastrostomy Tube)



(Left) *The patient later presented with bleeding via the G tube. DSA of the gastroepiploic artery → revealed a pseudoaneurysm → at the access site. Of note, the G tube has been removed over a guidewire ↪ so as to eliminate any possible tamponade effect by the tube.* **(Right)** *Coil embolization → of the gastroepiploic artery was performed. DSA demonstrates that the pseudoaneurysm has been successfully excluded.*

Gastrointestinal Balloon Dilatation and Stenting

KEY FACTS

PREPROCEDURE

- **Indications for gastrointestinal stenting**
  - Malignant stricture
  - Tracheoesophageal fistula
  - Temporizing measure prior to surgery
- **Contraindications for gastrointestinal stenting**
  - Gastrointestinal perforation/peritonitis
  - Gastric outlet or small bowel obstruction
  - Lesions that cannot be crossed with catheter/guidewire; excessively long lesions

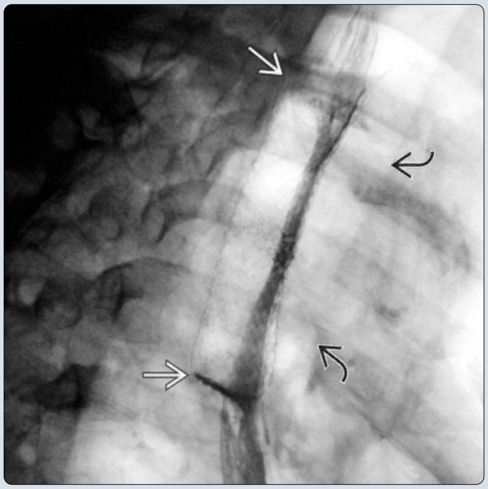
PROCEDURE

- To choose appropriate stent, assess
  - Location/length of stricture or fistula
  - Sufficient proximal/distal landing zones for stent
  - 1-2 cm of normal lumen proximal/distal to lesion
- Covered, self-expanding metallic stent
  - Malignant esophageal or colonic stricture
  - Tracheoesophageal fistula
- Noncovered, self-expanding metallic stent
  - Gastroduodenal stricture
  - Colonic stricture

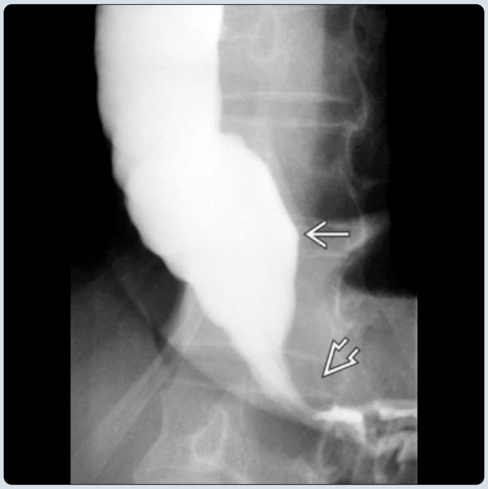
OUTCOMES

- High technical/clinical success rate (> 90%)
- Complications
  - Hemorrhage (usually mild/self-limiting)
  - Perforation (infrequent except in colon)
  - Stent obstruction (tumor ingrowth/food impaction)
  - Stent migration (more frequent with covered stents although less now with improved designs)

Stented Malignant Tracheoesophageal Fistula

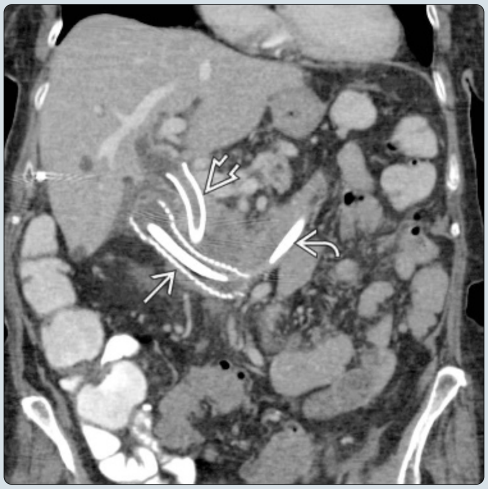


Achalasia

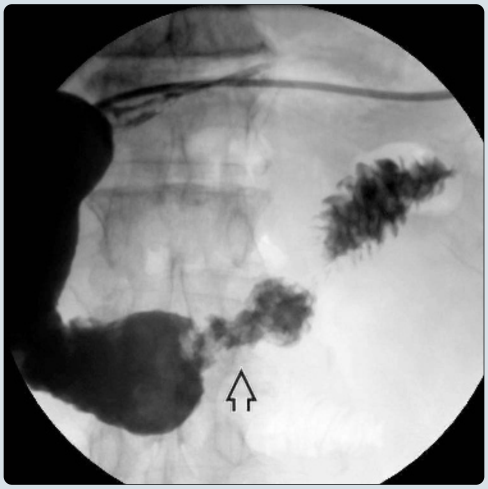


(Left) *Water-soluble contrast swallow in a patient with a history of a malignant tracheoesophageal fistula demonstrates a covered esophageal stent → in place and closure of the fistula, with no contrast seen in the trachea ↪.* **(Right)** *An upright barium esophagram shows marked dilation of esophageal lumen →, ending in a smoothly tapered "bird-beak" deformity ⇨. Peristalsis was absent. This diagnosis of achalasia is typically treated with surgery or balloon dilatation, not stenting.*

Stented Duodenal & Biliary Obstruction



Duodenal Mass



(Left) *A patient with metastatic melanoma causing duodenal and biliary obstruction is shown after placement of duodenal → and biliary stents ⇨. Note the gastrojejunostomy feeding tube ↪ coursing through the duodenal stent.* **(Right)** *Film from an upper GI series shows a soft tissue mass narrowing the 2nd portion of the duodenum ⇨. The mass was surgically resected and proved to be a large adenomatous polyp, precluding the need for either stent placement or balloon dilation.*

PREPROCEDURE

Indications

- **Esophagus**
  - Esophageal balloon dilatation
    - Benign esophageal stricture
      - ☐ Causes: Inflammatory/infectious esophagitis (75% of benign strictures due to peptic disease), foreign-body reaction, ingestion of caustic agents, radiation therapy, Schatzki ring, surgical stricture
    - Achalasia
      - ☐ Esophageal motility disorder characterized by diminished/absent peristalsis, increased lower esophageal sphincter pressure; no coordinated relaxation during swallowing
      - ☐ Lower success with balloon dilatation vs. surgery; Heller myotomy with fundoplication now considered procedure of choice in achalasia
  - Esophageal stenting
    - Malignant esophageal stricture or tracheoesophageal fistula (TEF)
      - ☐ Inoperable lesion or temporizing measure (e.g., prior to chemoradiation or surgery)
    - Extrinsic compression (e.g., adenopathy)
    - Benign stricture refractory to other treatments (e.g., unresponsive to balloon dilatation)
- **Stomach/duodenum**
  - Malignant gastroduodenal obstruction
    - Gastroduodenal tumor
    - Extrinsic malignancy (e.g., pancreatic neoplasm)
  - Malignant anastomotic obstruction
- **Colon/rectum**
  - Malignant obstruction or fistula
    - Unresectable; desire to avoid colostomy/ileostomy
    - Temporizing measure prior to surgery
  - Benign stricture
    - Temporizing measure prior to surgery

Contraindications

- **General**
  - Uncorrectable coagulopathy
  - Gastrointestinal perforation/peritonitis
  - Recent radiation (< 6 weeks)
    - Increases risk of hemorrhage/perforation
  - Gastric outlet or small bowel obstruction (e.g., peritoneal carcinomatosis)
  - Lesions that cannot be crossed with catheter/guidewire; excessively long lesions
- **Esophagus**
  - Malignancy involving upper esophageal sphincter
  - Should not stent leaks/fistulas due to benign disease
    - Leakage will occur around stent
- **Gastroduodenal**
  - Distal small bowel obstruction
- **Colorectal**
  - Lesion requiring stent extension to anal sphincter
  - Very proximal lesion (e.g., cecum)
    - May be more amenable to endoscopic approach

Preprocedure Imaging

- **Esophagus/stomach/duodenum**
  - Barium swallow/upper GI series
    - Characterizes abnormality
    - Delineates proximal/distal limits of stricture
  - Upper endoscopic evaluation
    - Further evaluation of esophagram findings
    - Biopsy for histologic diagnosis
  - CT
    - Evaluation of extrinsic compression of esophagus
    - Evaluate for tracheobronchial compression
  - Review abdominal/pelvic CT
    - Exclude distal small bowel obstruction
    - Exclude perforation/pneumoperitoneum
- **Colon and rectum**
  - Contrast enema: Characterize abnormality
    - Delineate proximal and distal limits of stricture
  - Colonoscopy: Biopsy if suspicious for malignancy

Getting Started

- Things to check
  - Clinical history and physical examination
    - Procedure indications
    - Current medications; any anticoagulant or antiplatelet agents
  - Laboratory parameters
    - Platelet count > 50,000/μL
    - Coagulation profile
      - ☐ International normalized ratio ≤ 1.5
      - ☐ Normal prothrombin time, partial thromboplastic time
- Medications
  - General
    - Procedural sedation: Typically fentanyl & midazolam
    - General anesthesia helpful in certain patients
  - Esophageal/gastroduodenal stenting: Lidocaine aerosol spray for oral anesthesia
  - Colorectal stenting: Cleansing enema prior to procedure
- Equipment list
  - Water-soluble nonionic contrast
  - Mouth guard (esophageal/gastroduodenal stenting)
  - 5-Fr directional catheter (e.g., Kumpe)
  - 0.035" stiff 180- to 260-cm guidewire (e.g., Amplatz)
  - Other guidewires may be necessary to cross stricture (e.g., 0.035" hydrophilic, 3J, Bentson)
  - Balloon dilatation catheter, if dilatation intended
    - Various diameters (6-20 mm)
    - 30-/35-/40-mm balloons (e.g., Rigiflex II; Boston Scientific; Natick, MA)
      - ☐ For achalasia dilatation
  - Stent (various proprietary options)
    - Esophagus
      - ☐ WallFlex/Ultraflex esophageal stent (Boston Scientific; Natick, MA); highly flexible covered/noncovered, for malignant strictures
      - ☐ Covered, self-expanding metallic stent for TEF
    - Gastroduodenal obstruction
      - ☐ Noncovered self-expanding metallic stent [e.g., Wallstent (Boston Scientific; Natick, MA)]
      - ☐ Ultraflex stent (Boston Scientific; Natick, MA); highly flexible covered/noncovered options
    - Colon/rectum

      - ☐ Covered/noncovered, self-expanding stent

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Left lateral decubitus position
    - May change patient position after negotiation through colorectal stricture

Procedure Steps

- **General**
  - Review preprocedure imaging carefully; verify
    - Prior contrast swallow, upper GI series, or enema
      - ☐ Verify location of stricture or fistula
      - ☐ Determine length of lesion
    - Assess proximal/distal landing zones for stent
      - ☐ Prefer at least 1-2 cm of normal lumen proximal and distal to abnormality
- **Esophagus**
  - Anesthetize oropharynx with lidocaine aerosol spray
  - Place mouthguard
  - Advance 5-Fr directional catheter (e.g., Kumpe) into esophagus above stricture
    - May use 3-J guidewire to catheterize esophagus
  - Remove guidewire
  - Inject water-soluble nonionic contrast to delineate boundaries of lesion/stricture
  - Negotiate lesion with guidewire and catheter
    - Consider angled hydrophilic or Bentson guidewire
  - Advance 0.035" stiff guidewire through catheter
    - Coil guidewire in stomach
  - Remove catheter
  - Choose appropriate stent for lesion
    - Various choices for stent selection
    - Choose stent at least 3-4 cm longer than stricture
      - ☐ May need overlapping stents in long strictures
    - Malignant stricture
      - ☐ Partially/fully covered, self-expanding metallic stent (e.g., WallFlex esophageal stent)
    - Cervical esophageal stricture
      - ☐ Consider softer Ultraflex stent (less pain risk)
    - Esophageal narrowing from extrinsic compression
      - ☐ Noncovered stent may be preferred
    - Massively dilated esophagus around stricture
      - ☐ Consider noncovered stent; reduced risk of food trapping between stent and esophageal wall
  - Advance stent delivery system over guidewire
    - Ideally, stent extends 2 cm above/below lesion
    - May position so stent extends more proximally above stricture than distally
      - ☐ If stent migration occurs, usually is distal
  - Unnecessary to predilate stricture unless difficulty advancing stent system through stricture
    - Risk of perforation with dilatation
  - If dilatation needed, use 10- to 15-mm diameter balloon
    - Advance balloon catheter over guidewire
    - Position catheter bridging lesion/stricture
    - Inflate balloon with dilute contrast
    - Deflate balloon; exchange for stent
  - Deploy chosen stent
    - Be familiar with stent deployment technique
      - ☐ WallFlex stent deployed by retracting sheath
      - ☐ Ultraflex stent deployed by retracting string
    - Stent typically expands distal to proximal
  - Stent may migrate distally during unsheathing
    - May retract system slowly to reposition
    - Generally possible to re-sheathe stent with up to 50% of stent deployed
  - Multiple overlapping stents may be needed
    - Goal is to bridge entire stricture
    - Need 1-2 cm of overlap between stents to reduce risk of stents separating/migrating
  - Exchange stent delivery catheter over guidewire for 5-Fr directional catheter; remove guidewire
  - Inject contrast; confirm stent position
- **Gastroesophageal junction stricture**
  - Classically, noncovered stents used
    - Increased stent migration risk with covered stent
      - ☐ Increased risk due to protrusion into stomach
  - Newer and improved designs make covered, self-expanding metallic stent first choice
    - Uncovered proximal and distal portions
    - Proximal flaring
    - Fabric along inside of metal lattice
- **Tracheoesophageal fistula**
  - Covered, self-expanding metallic stent
  - If tracheobronchial compression present
    - Consider placing tracheobronchial stent prior to esophageal stent; latter may exacerbate tracheobronchial compression
- **Stomach/duodenum**
  - Nasogastric tube decompression 1-2 days prior to procedure
  - Procedure similar to esophageal stenting
    - Peroral approach used whenever possible
    - Transgastrostomy stent placement is alternative
      - ☐ Useful with complex surgical anastomoses
  - Noncovered stent (e.g., Wallstent) usually preferred
    - Does not obstruct ampulla
    - Lower risk of stent migration compared to covered, self-expanding metallic stent
  - Assess degree of gastric distension
    - Consider distending collapsed stomach with air injection via catheter
      - ☐ Facilitates duodenal cannulation
  - If guidewire/catheter loops in stomach, may increase difficulty of duodenal cannulation
    - Use of 12-Fr sheath may be helpful
      - ☐ Stiffens guidewire/catheter
      - ☐ Prevents looping within stomach
  - Dilatation before stenting usually unnecessary
    - If required, use 10- to 15-mm diameter balloon
- **Colon/rectum**
  - Cannulate anus with 5-Fr catheter & 3-J guidewire
  - Advance catheter to level of stricture
  - Remove guidewire from catheter
  - Inject water-soluble contrast via catheter
    - Delineate proximal/distal limits of stricture
  - Negotiate guidewire and catheter through stricture
    - May require use of hydrophilic guidewire

  - Repeat contrast injection of catheter after negotiation through stricture may be helpful
    - Better delineation of distal limit of stricture
  - Advance 0.035" stiff guidewire (e.g., Amplatz)
  - Advance stent delivery system over guidewire
  - Predilatation of stricture usually unnecessary
    - Beware perforation risk in setting of friable tumor
    - Endoscopic assistance may be necessary
  - Deploy chosen stent so that lesion is spanned
  - Balloon dilatation rarely required after stenting
  - Obtain abdominal/pelvic radiograph after stenting

POST PROCEDURE

Things to Do

- **Esophagus**
  - May start clear liquid diet on day of procedure
  - Obtain esophagram day following procedure
    - Assess stent patency/expansion/position
      - Resume normal diet if satisfactory esophagram
  - Initiate proton-pump inhibitor therapy if stent straddles gastroesophageal (GE) junction
    - Stent position increases risk of GE reflux
      - Proton-pump inhibitors reduce gastric acid
  - Encourage consumption of carbonated beverages
    - Reduces risk of food impaction
- **Gastroduodenal obstruction**
  - Begin clear liquid diet after 24 hours
  - Obtain upper GI series day following procedure
    - Assess stent patency/expansion/position
      - Advance to semisolid/solid diet if satisfactory
  - Encourage thoroughly chewing food
    - Reduces risk of food impaction in stent
- **Colon/rectum**
  - Obtain abdominal/pelvic radiograph in 1-2 days
    - Assess stent position/expansion
    - Exclude bowel obstruction
  - Initiate stool softener therapy

Things to Avoid

- **Esophagus**
  - Do not stent across upper esophageal sphincter
    - Foreign-body sensation in throat
  - Avoid stent placement in patients with recent chemoradiation (< 6 weeks)
    - Increased risk of hemorrhage/perforation
  - Avoid placement of metallic stents in benign strictures
    - High rate of late complications

Postprocedure Imaging

- Water-soluble contrast swallow or upper GI series 24 hours after esophageal or gastroduodenal stenting
- Plain radiograph of abdomen/pelvis or water-soluble contrast enema 24-48 hours after colorectal stenting

OUTCOMES

Complications

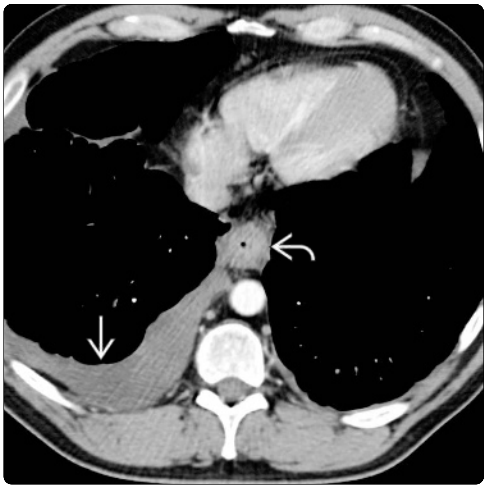
- Most feared complication(s)
  - Perforation
    - Rare with esophageal/gastroduodenal procedures
    - Colonic perforation (0-18%) may occur from guidewire manipulation injury
- Immediate/periprocedural complication(s)
  - Hemorrhage
    - Increased risk if recent radiation therapy
  - Stent damage
    - Ultraflex stent may be more fracture prone
  - Pain
    - Higher incidence with upper esophageal stent
    - Transient mild abdominal pain after gastroduodenal stenting not unusual
- Delayed complication(s)
  - Stent migration
    - More frequent with covered stents
    - May be treated with new overlapping stents
    - Complete stent migration may be asymptomatic
      - Endoscopic/surgical removal only if obstructed
  - Stent obstruction
    - Tumor ingrowth (↑ incidence with noncovered stents)
      - May be treated with new stent placement
    - Food impaction
      - Endoscopic removal
  - Biliary obstruction from duodenal stent
    - Percutaneous transhepatic biliary drainage
    - Endoscopic biliary drainage
  - Perforation
  - Tracheoesophageal stricture
    - Consider new esophageal stent placement
    - Consider tracheobronchial stent placement
  - Reflux
    - From esophageal stent extending across GE junction
      - Proton-pump inhibitor therapy

Expected Outcomes

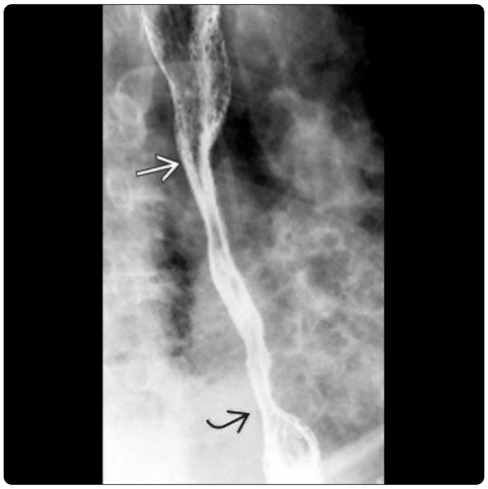
- **Esophagus**
  - Technical success rate for stricture: Near 100%
  - 92-98% improvement in dysphagia
    - At least 1 grade dysphagia score improvement
      - Grade 0: Normal diet
      - Grade 1: Some solid food
      - Grade 2: Semisolid food only
      - Grade 3: Liquids only
      - Grade 4: Complete dysphagia
  - > 67-100% clinical success in fistula closure with covered, self-expanding metallic stent
- **Gastroduodenal**
  - Technical success: 94-100%
  - Clinical success: ~ 90%
    - 10% clinical failure usually due to distal small bowel obstruction or lack of peristalsis
- **Colon/rectum**
  - Technical success: 93-96%
    - Failure usually due to tortuous colon or inability to negotiate stricture
  - Clinical success: > 90%
  - Recurrent obstruction in palliative stenting: 12-29%

SELECTED REFERENCES

1. Katsanos K et al: Stenting of the upper gastrointestinal tract: current status. Cardiovasc Intervent Radiol. 33(4):690-705, 2010

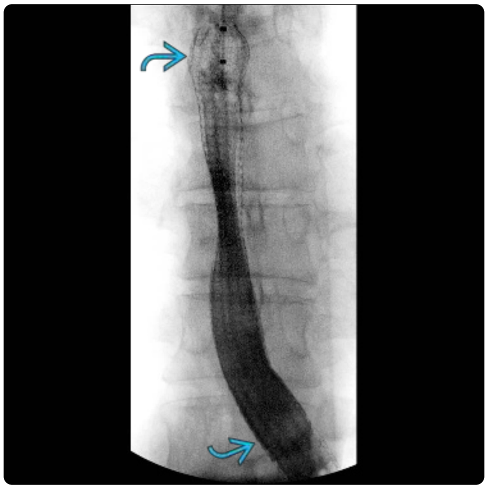


Esophageal Stricture Stenting (Initial CT Evaluation)

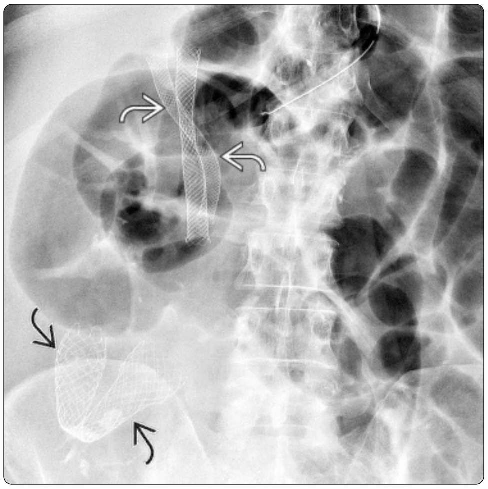


Esophageal Stricture Stenting (Initial Fluoroscopic Imaging)

(Left) *Axial CT of a 55-year-old man with history of esophageal adenocarcinoma and severe thickening of the distal esophagus* ➡ *is shown. A right pleural effusion* ➡ *is also noted.* **(Right)** *Barium swallow demonstrates the proximal* ➡ *and distal* ⇨ *limits of an extensive area of narrowing and mucosal irregularity in the distal esophagus, consistent with malignancy. Review of the esophagram prior to stent placement is important, as this aids in the selection of the appropriate stent type, diameter, and length.*

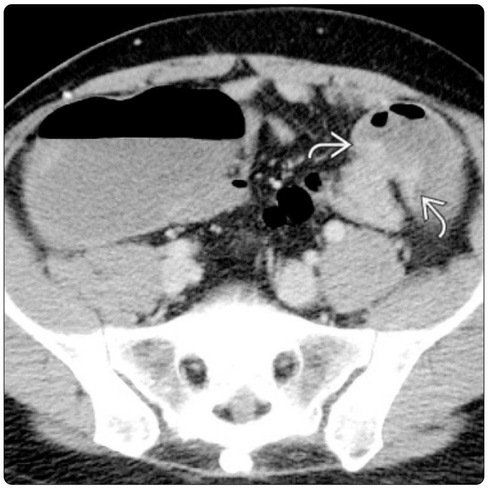


Esophageal Stricture Stenting (S/P Esophageal Stenting)

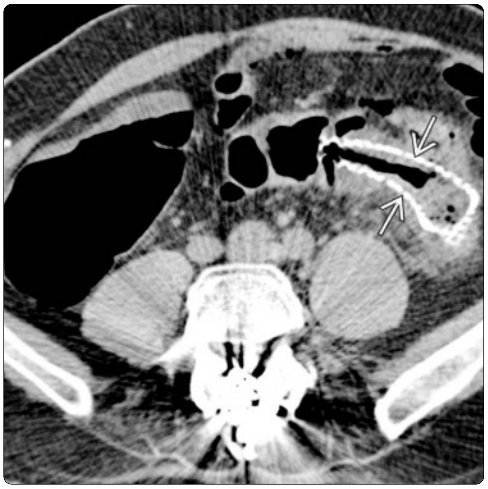


Lower Gastrointestinal Stenting (Ileocolic WallFlex Stent)

(Left) *Spot radiograph obtained during contrast esophagram shows that there has been placement of a covered Ultraflex esophageal stent* ⇨*. Covered stents placed for malignancy reduce the risk of tumor ingrowth when compared to noncovered stents.* **(Right)** *Abdominal radiograph obtained in a patient with metastatic gallbladder cancer demonstrates that a noncovered colonic WallFlex stent* ⇨ *has been placed across an obstructed ileocolic anastomosis. Biliary stents* ➡ *are also seen.*



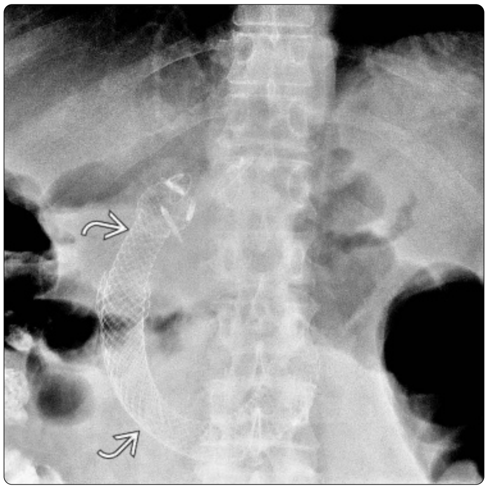
Colonic Stent Placement (Initial CT Evaluation)



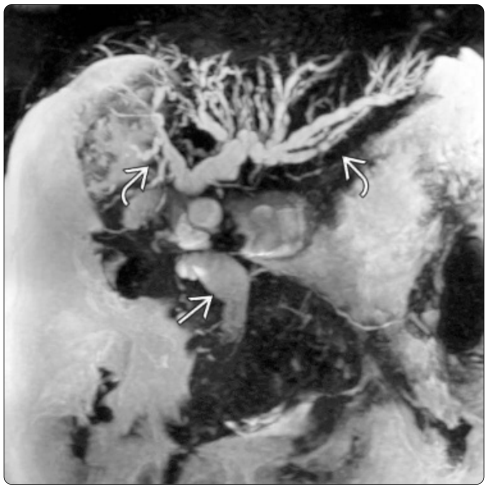
Colonic Stent Placement (Follow-Up CT Evaluation)

(Left) *A patient with severe abdominal pain and distention has a completely obstructing mass* ➡ *in the sigmoid colon.* **(Right)** *Axial NECT in the same patient shows interval placement of a colonic WallFlex stent* ➡ *across the malignant stricture. The stent is delivered via an over-the-wire system, and the ends are flared to minimize migration risk. Stent placement can serve either as a palliative or a temporizing measure in malignant colonic obstruction. This patient subsequently underwent colectomy.*

Complication of Duodenal Stenting (Initial Abdominal Radiograph)

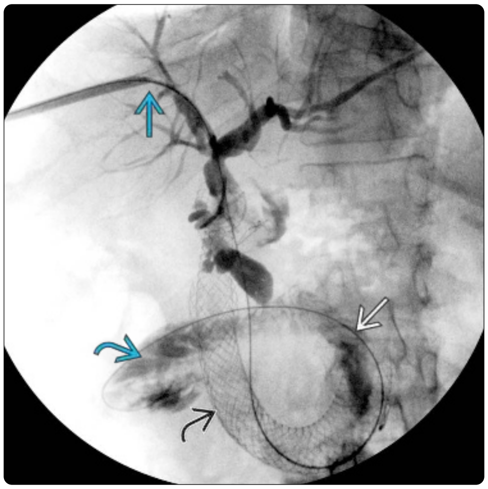


Complication of Duodenal Stenting (Biliary Obstruction on MRCP)

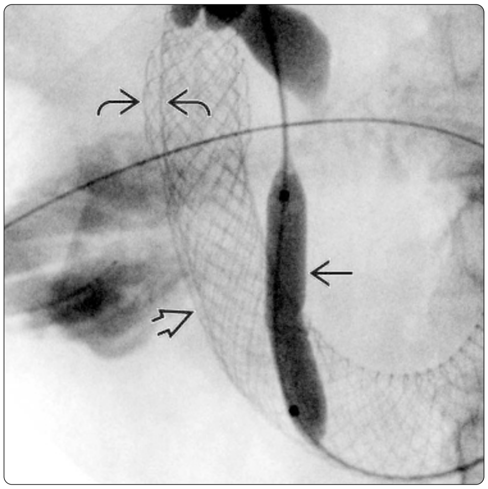


(Left) *A patient with metastatic transitional cell carcinoma has 2 endoscopically placed overlapping WallFlex stents ↪ in the 2nd and 3rd portions of the duodenum. The patient presented 2 weeks later with right upper quadrant pain and jaundice.* **(Right)** *Biliary obstruction developed after duodenal stenting. There is severe intrahepatic ↪ and extrahepatic → ductal dilatation. Biliary obstruction is a known complication of both noncovered and covered duodenal stents.*

Complication of Duodenal Stenting (Percutaneous Biliary Drainage)

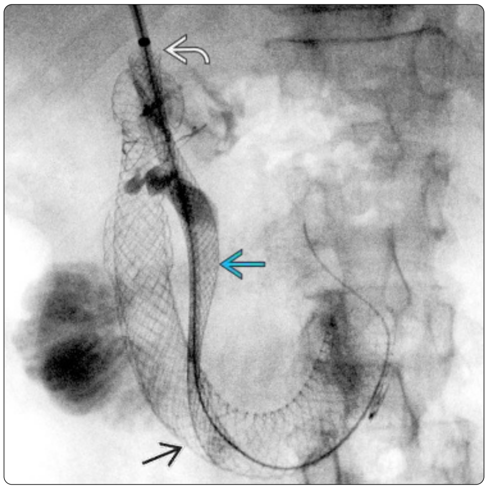


Complication of Duodenal Stenting (Percutaneous Biliary Stent Placement)

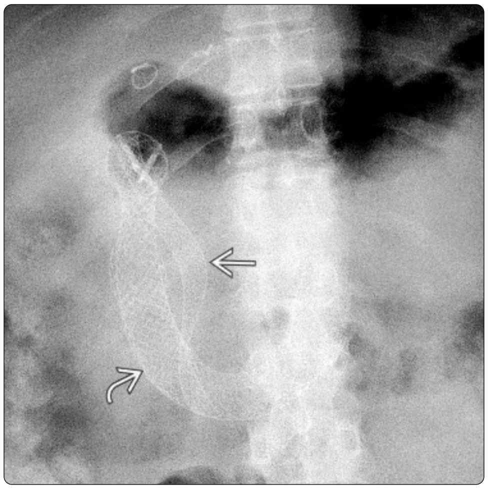


(Left) *Percutaneous biliary drainage was performed to decompress the obstruction. After gaining access through a right biliary radicle →, a guidewire → was advanced through the interstices of the duodenal stent ↪ into the jejunum ↪.* **(Right)** *A balloon → was advanced over the guidewire and was inflated across the interstices of the duodenal stent ⇨ to facilitate passage of the biliary stent delivery system. Note the overlap ↪ of the 2 duodenal WallFlex stents.*

Complication of Duodenal Stenting (Percutaneous Biliary Stent Placement)



Complication of Duodenal Stenting (S/P Decompressive Biliary Stenting)



(Left) *After balloon dilatation, a noncovered Wallstent → was deployed, extending from the intrahepatic biliary ductal bifurcation ↪ well into the duodenal stent →. A safety biliary catheter was subsequently placed and removed the next day.* **(Right)** *Subsequently, biliary decompression was successful via biliary stent → extending into the duodenal stent ↪. In cases of simultaneous duodenal and biliary obstruction, biliary and duodenal stents may be deployed side by side at the outset.*

KEY FACTS

TERMINOLOGY

- **Percutaneous transhepatic cholangiography (PTC)**: Minimally invasive radiologic technique used to visualize biliary tract anatomy
- **Percutaneous transhepatic biliary drainage (PTBD)**: Drainage catheter placement in biliary tract

PREPROCEDURE

- Indications
    - Biliary obstruction or leak
    - ERCP not possible
- Preprocedure imaging
    - Assess duct dilatation, level of obstruction
    - Assess for lobar atrophy, hepatic masses, ascites

PROCEDURE

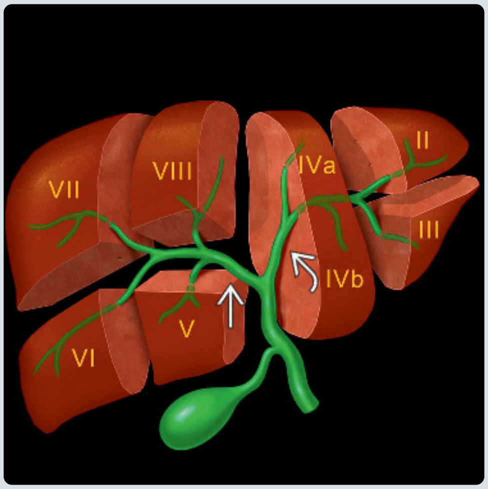
- For PTBD, lobe to drain depends on
    - Site of obstruction/biliary anatomy
    - Hepatic lobar volume
- Ultrasound- or fluoroscopic-guided access
- Drain placement using 1-stick or 2-stick technique
- Plan external drainage if
    - Unable to cross obstruction
    - Septic/hemodynamically unstable
- Prefer metal over plastic stent in nonresectable malignancy; prefer peripheral access

OUTCOMES

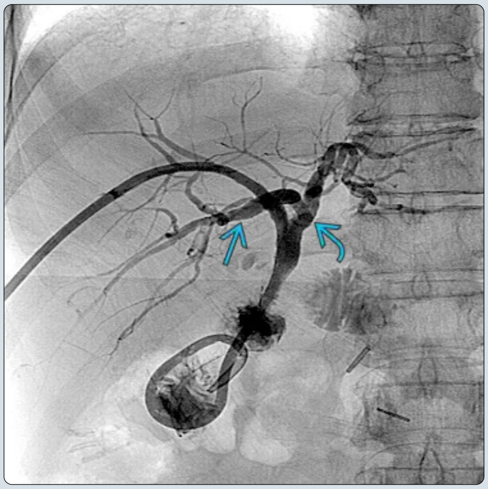
- Dilated ducts: > 95% technical success
- Nondilated ducts: 65-80% technical success
- Complications
    - Sepsis
    - Hemobilia/pseudoaneurysm

(Left) *Graphic shows a common biliary drainage pattern. The right hepatic duct* → *drains segments V-VIII, and the left duct* ↪ *drains II-IV. Variation in drainage patterns exists; review of MRCP/PTC prior to intervention is important.* **(Right)** *Spot radiograph from a biliary tube cholangiogram demonstrates variant biliary anatomy with the right posterior biliary duct* → *draining into the left biliary duct* ↪.

Biliary System Graphic

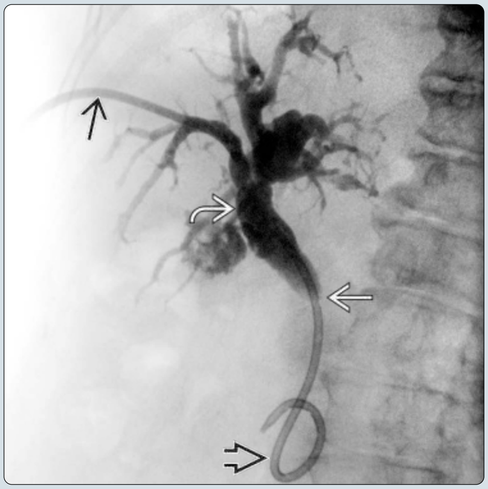


Variant Biliary Anatomy

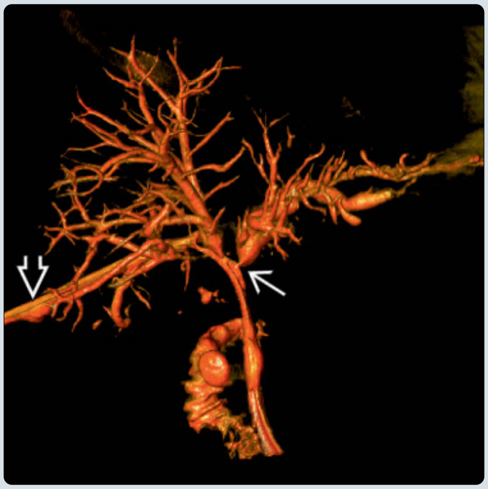


(Left) *Spot radiograph demonstrates an internal/external biliary drain* → *with the pigtail* ⇨ *loop in the bowel. There is biliary ductal dilatation* ↪ *due to a common duct stricture* →*, through which the drain has been passed.* **(Right)** *Cholangiogram was unable to localize suspected stenosis of left biliary system, revealed* → *on cone-beam CT. This image was obtained by injecting Omnipaque contrast through PBD* ⇨ *at 1 mg/second, 12 cc total, with 10-second x-ray delay.*

Abnormal Biliary Dilatation



Cone-Beam CT Cholangiogram



TERMINOLOGY

Definitions

- **Percutaneous transhepatic cholangiography (PTC)**: Minimally invasive radiologic technique used to visualize biliary tract anatomy
  - Needle introduced through skin into liver to access biliary tract and inject contrast medium
  - Usually combined with percutaneous intervention
- **Percutaneous transhepatic biliary drainage (PTBD)**: Placement of drainage catheter into biliary tract
  - External drainage: Percutaneous biliary drain with catheter tip in biliary system
  - Internal/external drainage: Percutaneous biliary drain with catheter tip in bowel

PREPROCEDURE

Indications

- Biliary obstruction
  - Malignancy
  - Anastomotic stricture
  - Choledocholithiasis
- Biliary leak
  - e.g., post cholecystectomy
  - Excluded segmental bile duct leak (ESBDL)
    - Surgical complication resulting from division and exclusion of bile ducts from functional, segregated segment of liver
- Endoscopic retrograde cholangiopancreatography (ERCP) not possible (e.g., post Whipple procedure)

Contraindications

- Uncorrectable coagulopathy
- Multisegmental obstruction
  - Narrowing at multiple higher order branches may not be amenable to drainage

Preprocedure Imaging

- Liver MR with MRCP
  - Demonstrates biliary anatomy/level of obstruction
  - Normal anatomy
    - Right anterior duct drains segments V and VIII
      - Typically courses in vertical orientation
    - Right posterior duct drains segments VI and VII
      - Typically courses horizontally
    - Right anterior & posterior ducts join to form right main duct
    - Right & left main ducts join; form common duct
  - Variant anatomy common
    - Right posterior or sometimes right anterior duct joins left main duct
    - Right anterior, posterior, & left main duct form triple confluence
- Hepatobiliary scintigraphy
  - Used to confirm presence of biliary leak

Getting Started

- Things to check
  - Clinical history and physical examination
    - Procedure indications
    - Current medications
      - Any anticoagulant or antiplatelet agents
  - Allergies
  - Laboratory parameters
    - Complete blood count (CBC)
      - Platelet > 50,000/μL
    - Coagulation profile
      - International normalized ratio (INR) ≤ 1.5
      - Normal prothrombin time (PT), partial thromboplastin time (PTT)
    - Liver function tests
      - Elevated bilirubin, alkaline phosphatase in biliary obstruction
    - Estimated glomerular filtration rate (eGFR)
      - Reduced eGFR may impact prophylactic antibiotic regimen
  - Review pre-procedure imaging
    - Assess duct dilatation, level of obstruction
    - Assess for parenchymal atrophy
      - Drainage may not be beneficial in atrophic hepatic lobe
    - Evaluate for presence of hepatic masses
      - Metastases
      - Large cysts
    - Evaluate for presence of ascites
  - Obtain procedural/sedation consent
- Medications
  - Anesthesia
    - 1% lidocaine local anesthetic
    - Procedural sedation
      - Fentanyl, midazolam typically used
    - Anesthesiology assistance if necessary
      - Hemodynamically labile patients
  - Prophylactic antibiotics
    - Many possibilities
      - Ampicillin (1 g); gentamicin (80 mg)
      - Piperacillin/tazobactam (3.375 g)
  - IV hydration
- Equipment list
  - **General**
    - Ultrasound equipment
      - 3- to 5-MHz transducer
      - Sterile probe cover/gel
    - Fluoroscopy equipment
  - **1-stick technique**
    - 21- to 22-g Chiba needle
    - 0.018" mandril or nitinol guidewire
    - 6- to 8-Fr guidewire exchange set
    - 0.035" 3-J guidewire or similar
    - 0.035" Amplatz guidewire or similar
    - 4- to 5-Fr directional catheter (e.g., Kumpe)
    - 8-Fr dilator
  - **2-stick technique**
    - 21- to 22-g Chiba needle
    - Longdwell or 19-g ultrathin Chiba needle
    - 0.035" 3-J guidewire or similar
    - 0.035" Amplatz guidewire or similar
    - 5-Fr directional catheter (e.g., Kumpe)
    - 8-Fr dilator
  - **To cross obstruction**

        - Hydrophilic guidewire
        - Quick-cross or hydrophilic catheter
    - **Biliary drain**
        - 8-Fr locking pigtail catheter for external drainage
        - 8-Fr locking biliary drain for internal/external drainage (i.e., 32 sideholes)
    - **Balloon dilatation**
        - Sheath
        - 0.035" Amplatz guidewire
        - Angioplasty balloon catheter
            - 6-10 mm diameter
            - 4-8 cm length
    - **Biliary stent**
        - Sheath
        - 0.035" Amplatz guidewire
        - Stent
    - **Endobiliary biopsy**
        - 0.035" Amplatz guidewire
        - 3-mm biopsy brush
        - Forceps biopsy device
            - e.g., 5.2-Fr clamshell forceps
    - **Percutaneous stone removal**
        - Sheath
        - 0.035" Amplatz guidewire
        - Fogarty balloon, stone retrieval device (e.g., basket)

PROCEDURE

Patient Position/Location

- Best procedure approach
    - Right/left/bilateral drainage may be performed
    - Right-sided access generally preferred
        - Straighter course for wire/catheter manipulation
        - May have higher radiation exposure to operators' hands with left-sided access
    - For PTBD, appropriate lobe to drain depends on
        - Site of obstruction
            - Right or left drainage usually sufficient for distal common duct obstruction
            - If confluence obstruction, may perform bilateral drainage or unilateral drainage of larger lobe
        - Biliary anatomy
            - If right anterior or right posterior duct joins left duct, left-sided drainage may be preferred
        - Lobar volume
            - Avoid drainage of atrophied lobe
        - Presence of hepatic masses
        - Major ascites
            - Left-sided drain may have lower likelihood of fluid leakage from percutaneous access site
        - Lithotripsy
            - Drain placement peripheral to obstructing stone
    - **Right PTC/PTBD access**
        - Patient supine on fluoroscopy table
        - Right mid-axillary line approach
        - 9th to 11th intercostal space
            - Ask patient to take deep breath; prefer access below lung margin
        - Advance needle, initially parallel to table, toward T12 vertebral body
            - Alternatively, may access dilated duct directly using ultrasound guidance, if visible
    - **Left PTC/PTBD access**
        - Patient supine on fluoroscopy table
        - Subxiphoid or subcostal approach
        - Visualize dilated duct with ultrasound
            - If accessible, segment II duct preferred: Forms less acute angle with left main duct
            - Segment III duct courses vertically; may be more accessible than segment II duct

Procedure Steps

- **General**
    - Review preprocedure images; verify
        - Right, left, or bilateral drainage
        - Presence of major ascites may require paracentesis
    - Cleanse skin with preparatory solution and place sterile drapes to isolate sterile field
- **Right-sided PTBD**
    - **Fluoroscopic-guided initial needle placement**
        - Select needle puncture site
            - Right mid-axillary line
            - 9th to 11th intercostal space
        - Administer 1% lidocaine local anesthetic
        - Nick skin with #11 blade
        - Advance 21- to 22-g Chiba needle parallel to table toward T12 vertebral body
    - **US-guided initial needle placement**
        - Place sterile cover on transducer
            - First apply gel on probe
            - Apply sterile gel externally over probe cover
        - Visualize dilated duct
        - Administer 1% lidocaine local anesthetic
        - Nick skin with #11 blade
        - Advance Chiba needle into visualized duct
    - **After introducing Chiba needle**
        - Remove inner stylet
        - Inject small contrast aliquots under fluoroscopy
            - Intrabiliary injection shows candle-wax-like flow of contrast toward hilum
            - Flow toward IVC indicates needle tip located in hepatic vein
            - Flow toward liver periphery indicates hepatic arterial or portal venous intravasation
        - If no bile duct opacification
            - Slowly retract needle and inject small aliquots
            - Avoid large-volume injections as extraluminal contrast may obscure cholangiography
            - Stop retraction at liver edge; avoid removing needle from liver (minimizes capsular punctures/bleeding risk)
            - Advance needle in more inferior orientation and repeat; may also consider more anterior/posterior orientation
        - Perform cholangiogram after duct accessed
            - Obtain AP and oblique views
            - Assess point(s) of obstruction
    - **1-stick technique**
        - If initial access in suitable duct peripheral to obstruction, advance 0.018" guidewire into duct

    - Exchange needle for 6- to 8-Fr guidewire exchange set
    - Unscrew inner dilator/stiffener; advance outer sheath further into duct if possible
    - Remove guidewire and inner dilator/stiffener
    - Advance 0.035" guidewire into duct
    - Advance 4- to 5-Fr directional catheter through outer sheath
      - e.g., Kumpe, multipurpose angled catheter
    - Negotiate catheter/guidewire through obstruction
      - Use contrast injection via catheter as necessary
    - If unable to pass obstruction
      - Use hydrophilic guidewire
      - Quick-cross or hydrophilic catheter
    - Plan external drainage if
      - Unable to cross obstruction
      - Septic/hemodynamically unstable
    - **External drain**
      - Dilate skin & soft tissue tract over guidewire
      - Advance 8-Fr locking pigtail catheter over guidewire into biliary duct
      - Remove guidewire from pigtail catheter
      - Form pigtail loop in duct
      - Inject contrast, confirm location; catheter should drain ducts peripheral to obstruction
    - **Internal/external drain**
      - Once through obstruction, advance guidewire/catheter into bowel
      - Exchange wire for 0.035" Amplatz guidewire
      - Dilate skin & soft tissue tract over guidewire
      - Advance 8-Fr biliary drain; position tip in bowel
      - Remove guidewire
      - Perform contrast injection to confirm location
      - Retract catheter until sideholes above and below level of obstruction
  - **2-stick technique**
    - Select peripheral duct on cholangiogram performed from initial needle placement
    - Administer 1% local anesthetic
    - Nick skin with #11 blade
    - Advance Longdwell sheathed needle (e.g., Ring) into duct using fluoroscopic guidance
    - Remove needle; leave sheath indwelling
    - Advance 0.035" 3-J guidewire into duct via sheath
    - Exchange sheath for 5-Fr directional catheter
      - e.g., Kumpe, multipurpose angled catheter
    - Perform contrast injection to confirm location
    - Negotiate obstruction or leave external drain
      - As described with 1-stick technique
  - May place 9- to 10-Fr peel-away sheath prior to drain deployment for added stability
- **Left-sided PTBD**
  - Ultrasound-guided access
    - Performed as with right-sided drainage except anterior subxiphoid/subcostal approach
    - Nick skin with #11 blade
  - Fluoroscopic-guided access
    - Costal and xiphoid margins may limit access
    - Liver may rise considerably into chest with moderate sedation (due to shallow inspirations)
      - Makes access to left lobe challenging
    - Feasible if cholangiogram available for guidance
    - Perform initial access with right-sided PTC and opacify left biliary ductal system
      - Left ducts are anterior and anti-dependent compared to right ducts
      - Reverse Trendelenburg position facilitates contrast opacification of left system
    - Select duct on cholangiogram and proceed using 2-stick technique with Longdwell needle
- **Biliary dilatation**
  - Generally not performed at outset in septic/hemodynamically unstable patients
  - Obtain percutaneous biliary access
    - Obtain cholangiogram to demarcate proximal/distal limits and severity of stenosis
  - Place Amplatz guidewire across stenosis into bowel
  - Advance sheath over guidewire
    - Choose sheath size according to planned size of internal/external drain
  - Advance balloon catheter across stenosis
    - Balloon diameter: 6-10 mm
      - Smaller balloons for intrahepatic ducts
      - 10-mm balloon for common duct
    - Balloon length: 4-8 cm
  - Inflate angioplasty balloon with dilute contrast
    - Can inflate using insufflator device
    - "Waist" in balloon demarcates stenosis
    - Maintain angioplasty balloon inflation for 1 minute after waist disappears
      - Repeat for total of 3 inflations
  - Obtain repeat cholangiogram after angioplasty
- **Biliary stenting**
  - Self-expanding metallic stent most commonly used in setting of percutaneous access
    - Generally placed in nonsurgical malignant disease
      - Most metal stents nonretrievable
    - Covered and uncovered stents available
      - Benefit of one vs. other unclear
  - Place Amplatz guidewire across stenosis into bowel
  - May perform balloon dilatation of stenosis prior to introducing stent, if not already done
  - Advance catheter containing stent along wire
    - Metal stents typically expand/shorten with time
    - Proximal edge of stent should be placed at least 2-3 cm proximal to stenosis
    - Place distal edge of stent 2-3 cm beyond stenosis
      - Distal end may be advanced into bowel
  - Stent deployment will vary with manufacturer
    - Most self-expanding metallic stents constrained inside outer delivery sheath
      - Retract sheath to expose self-expanding stent
    - Stent has tendency to move forward
      - Adjust/retract catheter/stent as necessary while deploying to maintain satisfactory position
  - Inject contrast through sheath to confirm patency and position
  - Deploy 5- to 8-Fr safety catheter inside stent
  - Maintain safety catheter 1-7 days
    - Repeat cholangiogram

    - If patent stent with appropriate position, may remove safety catheter
  - May need 2 stents for ductal confluence disease
    - Bilateral biliary drains in place
    - Deploy stent along right duct, other stent along left duct; extend both into common duct
      - Stent will be parallel in common duct
    - May be possible to fashion "T" stent configuration via unilateral biliary access
      - Advance wire from left or right duct into contralateral duct using directional catheter
      - Deploy stent extending from right into left main duct across confluence to form top of "T"
      - Advance wire through stent into common duct
      - Balloon dilate struts of stent
      - Advance 2nd stent vertically through dilated struts into common bile duct to complete "T"
- **Endobiliary biopsy**
  - Send bile for cytology
  - **Brush biopsy**
    - Place 0.035" Amplatz safety guidewire across biliary ductal stenosis into bowel
    - Advance sheath to distal end of stenosis
    - Advance biopsy brush just distal to sheath
    - Retract sheath
    - Move biopsy brush to-and-fro across stenosis
    - Remove biopsy brush
    - Cut brush and deposit in saline
    - Repeat with 2nd brush
    - Send promptly to cytology
  - **Forceps biopsy**
    - Place 0.035" Amplatz safety guidewire across biliary ductal stenosis into bowel
    - Advance sheath over guidewire to edge of stenosis
    - Advance forceps via sheath/adjacent to stenosis
    - Obtain specimen; remove forceps
    - Place specimens in formalin; submit to pathology
- **Percutaneous stone removal**
  - Once percutaneous access to biliary tree has been established
  - Place safety wire into small bowel
  - Advance sheath into biliary tree
  - Inject contrast through side arm of sheath to opacify biliary system and locate stone
  - Advance Fogarty balloon over wire and gently inflate with air proximal to stone
    - Advance inflated balloon over wire to push stone into small bowel
    - May require balloon dilation of stricture or ampulla prior to pushing stone out
  - Or, advance biliary stone retrieval device (e.g., basket) through sheath while maintaining safety wire into bowel
    - Use retrieval device to capture stone and crush into smaller pieces or remove through sheath
    - May require subsequent balloon sweep through duct to clear debris into small bowel
- **Excluded segmental bile duct leak (ESBDL)**
  - Rare complication
  - Suspect ESBDL in postoperative patients with confirmed bile leak, but no evidence of leak on cholangiography or ERCP
  - Percutaneous drain placement into biloma may be necessary to diagnose ESBDL
    - Can forcefully inject biloma drain to reflux contrast into excluded biliary system
    - Excluded biliary system can then be accessed as detailed above
  - Treatment options
    - Liver resection considered definitive, but can be challenging with high morbidity
    - Glue embolization of excluded biliary segment
      - Once percutaneous access has been achieved into excluded biliary system
      - Glue injected to fill and embolize biliary system
      - May require repeated procedures
      - Associated liver segment will atrophy
    - Portal vein embolization of excluded segment
- **Catheter fixation**
  - Tie sutures along catheter at point at least 2 cm away from skin exit site
    - Allows for some catheter "give" with respiratory/body movement
    - Rigid catheter fixation at skin exit site increases risk of dislodgement
      - Portion of catheter may coil in intraperitoneal space between abdominal wall and liver capsule
      - Catheter may retract, dislodging sideholes from biliary tree or into intraperitoneal space

Findings and Reporting

- **PTC/PTBD**
  - Normal or variant biliary anatomy
  - Site(s) of obstruction; type of procedure
  - Unilateral or bilateral drainage performed
    - External vs. internal/external drainage
  - How obstruction was crossed
    - Hydrophilic guidewire, etc. required?
  - Choledocholithiasis
- **Biliary dilatation**
  - Diameter and length of balloon used
  - Appearance pre/post dilatation
- **Biliary stent**
  - Type, length, and diameter of stent(s) deployed
  - Indicate if safety catheter left indwelling
- Indicate if specimens sent for microbiology, cytology

Alternative Procedures/Therapies

- Radiologic
  - Percutaneous cholecystostomy
    - May be used to provide access to distal common bile duct abnormality
- Surgical
  - Open or laparoscopic surgical decompression
    - e.g., choledochojejunostomy, Whipple procedure
- Other
  - Endoscopic retrograde cholangiopancreatography
  - Combined percutaneous/endoscopic intervention
    - Rendez-vous procedure
      - Helpful in biliary transection

      - Gain percutaneous access into proximal limb
      - Gain endoscopic access into distal limb
      - Place snare catheter via percutaneous access; use to snare endoscopic guidewire in distal limb
      - Place internal/external drain &/or stent across area of biliary transection

POST PROCEDURE

Things to Do

- Watch for sepsis post procedure
  - IV hydration and IV antibiotics
- Follow-up liver function tests
  - May see rise in serum bilirubin initial few days after procedure prior to subsequent decrease
- Flush biliary drain with 10 mL normal saline twice daily using following regimen
  - 5 mL toward patient, 5 mL toward drainage bag
- Formulate management plan
  - Conversion of external to internal/external drain
  - Balloon dilatation &/or stent placement
  - Drain upsize
    - May require long-term, large (12- to 14-Fr) catheter drainage in treatment of benign biliary stricture
  - Assess need for additional drains

Things to Avoid

- Point of access into biliary system critical to success of future interventions; avoid suboptimal access
  - Prefer peripheral biliary access
- Proximal edge of stent should be at least 2-3 cm proximal to stenosis; do not place within stenosis
- Catheter and stent manipulations difficult when acute angles encountered; avoid acute angles
  - Consider selection of peripheral ducts that form gentle angles distally
- Pleural transgression; carries potential risks
  - Pneumothorax/pleural effusion/empyema

OUTCOMES

Complications

- Most feared complication(s)
  - Pseudoaneurysm
- Immediate/periprocedural complication(s)
  - Hemobilia
  - Pneumothorax
  - Sepsis
  - Subcapsular hematoma
- Delayed complication(s)
  - Hemobilia/pseudoaneurysm
    - Check hematocrit
    - If patient unstable
      - Obtain DSA; perform embolization as needed
    - If hemodynamically stable, obtain tractogram
      - Reposition drain if sideholes outside biliary tract
      - If venous system opacified, replace/upsize catheter for tamponade
      - If arterial opacification, may need angiographic evaluation/possible embolization
      - If hematocrit drop but no opacification of vascular structures, must still consider angiography/embolization
  - Bile peritonitis
    - Dislodged catheter with intraperitoneal bile leak
  - Stent occlusion by tumor ingrowth
    - May require new drainage
    - May cross occluded stent with guidewire; place additional stents within occluded lumen
- Other complications
  - Pleural transgression
    - Pleural effusion/empyema
  - Electrolyte depletion
    - Due to high-output external drainage
    - Requires repletion

Expected Outcomes

- Technical success rate for PTC/PTBD
  - Dilated ducts: 95-100%
  - Nondilated ducts: 65-80%
- Metallic stent patency at 12 months: 50-75%

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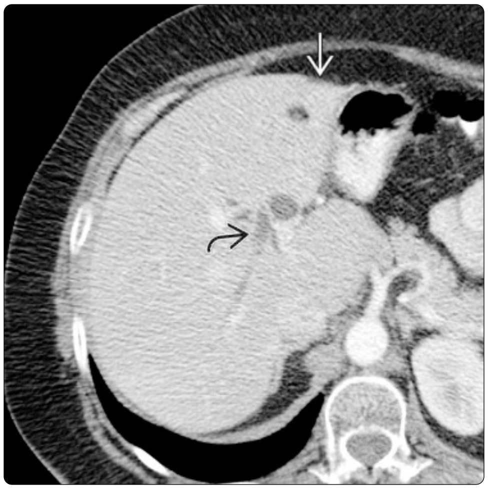
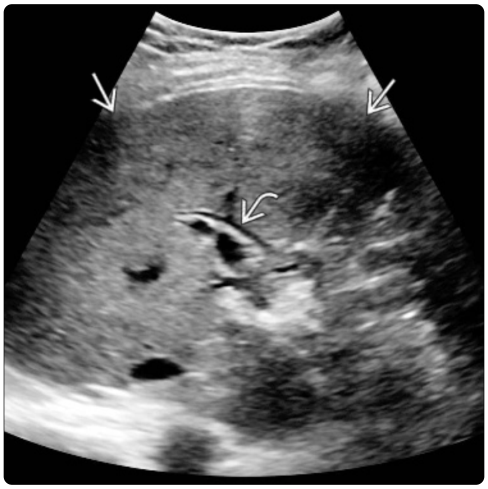
Step-by-Step: PTBD (Initial CT Imaging Evaluation)

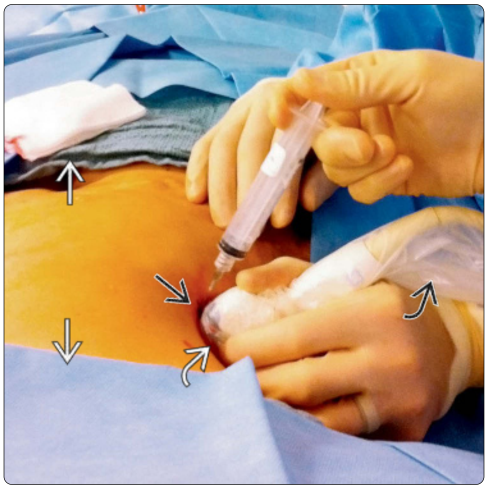


Step-by-Step: PTBD (Initial Ultrasound Imaging)

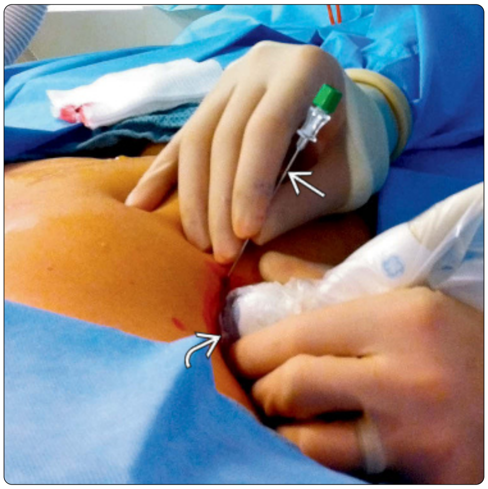


(Left) *Axial CECT demonstrates intrahepatic biliary ductal dilatation ↪ and left hepatic lobe atrophy → in a 54-year-old woman with a history of a Roux-en-Y hepaticojejunostomy.* **(Right)** *Preliminary US of the liver prior to percutaneous transhepatic biliary drainage demonstrates intrahepatic biliary ductal dilatation ↪ in the right hepatic lobe →. The initial needle placement can be performed using sonographic guidance. Alternatively, fluoroscopic guidance may be used for needle placement.*

Step-by-Step: PTBD (Site Preparation and Anesthesia)

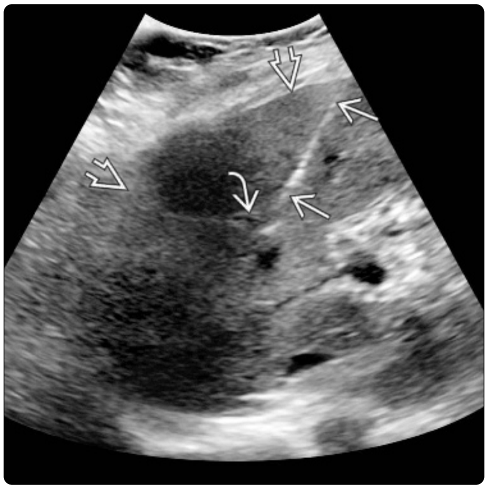


Step-by-Step: PTBD (Initial US-Guided Needle Access)

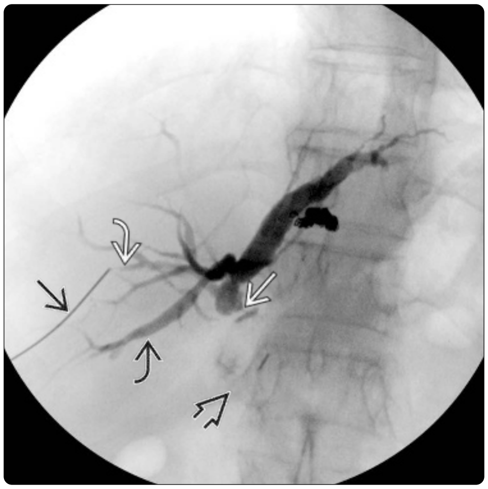


(Left) *Photograph shows appropriate sterile preparation with barrier drapes → for PTBD procedure. An ultrasound probe ↪ with a sterile cover ↪ can be used to identify and align the target intrahepatic duct into sonographic view. The planned needle entry site → is then anesthetized with 1% lidocaine. The anesthetic is administered all the way to the liver capsule.* **(Right)** *Photograph shows a 21-g Chiba needle → being inserted into the anesthetized skin site under direct sonographic ↪ visualization.*

Step-by-Step: PTBD (Initial US-Guided Needle Access)

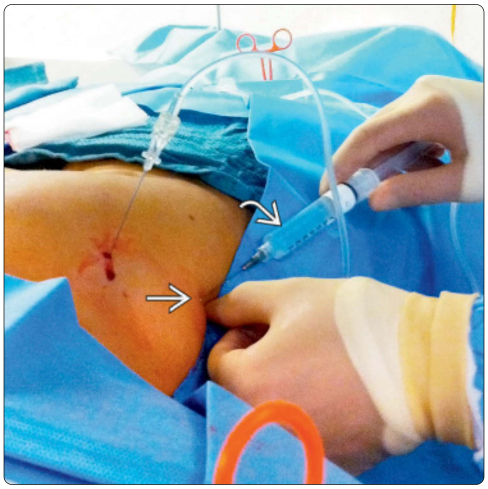


Step-by-Step: PTBD (Initial Cholangiography)

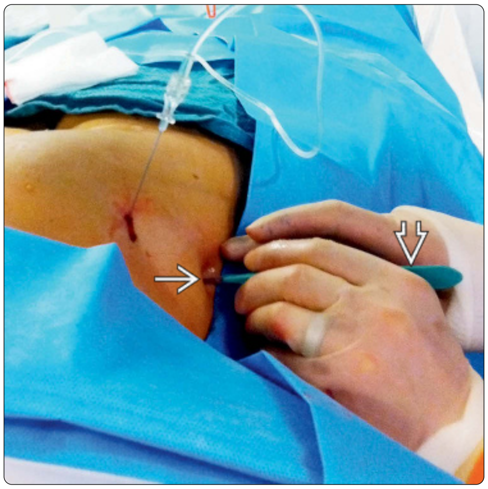


(Left) *Axial US of the right hepatic lobe ⇨ shows that the tip of the Chiba needle → has been advanced into a biliary duct ↪. Efflux of bile may be observed upon removal of the inner stylet to confirm needle tip position.* **(Right)** *After confirming bile return, cholangiography with multiple oblique views is performed. The needle → is in a small peripheral duct ↪. Note the anastomotic stricture → and the faint partial bowel opacification ⇨. A dilated peripheral duct ↪ is selected for drain placement.*

Step-by-Step: PTBD (Second Access Site Preparation)

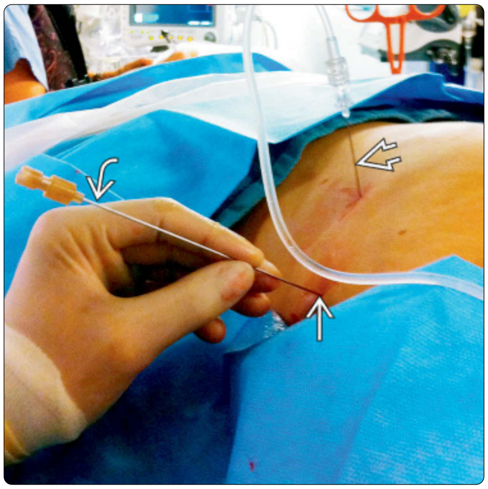


Step-by-Step: PTBD (Second Access Site Preparation)

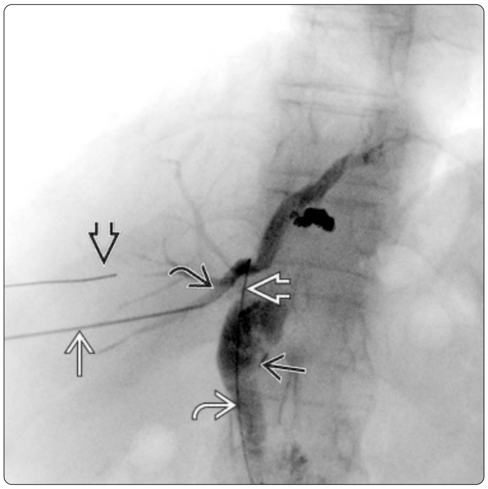


(Left) *A 2nd skin site →, for introduction of the drainage catheter is initially prepared by administering 1% lidocaine as local anesthetic ↪. Site selection for the 2nd point of access is performed by placing a hemostat over the potential site and evaluating under fluoroscopy to determine if a suitable intercostal trajectory is available.* **(Right)** *A small dermatotomy → is then made in the anesthetized area, using a #11 scalpel ⇨. The dermatotomy should be large enough to permit the placement of an 8-Fr drainage catheter.*

Step-by-Step: PTBD (Gaining Second Access)

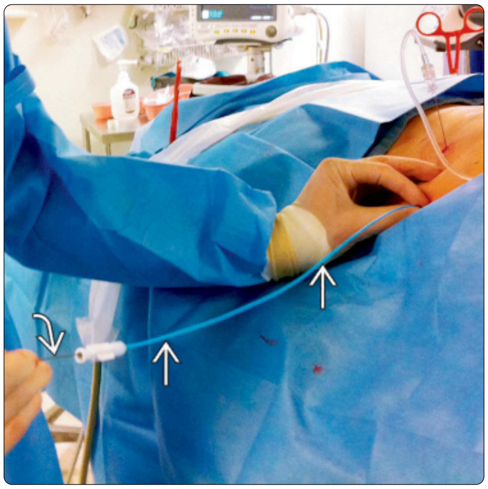


Step-by-Step: PTBD (Second Access Fluoroscopy)

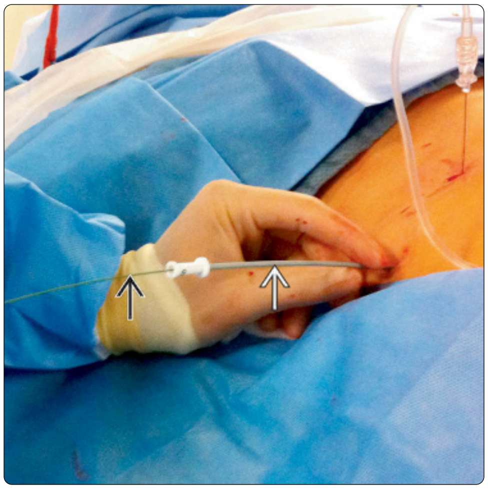


(Left) *A 19-g ultrathin Chiba needle ↪ is advanced through the skin → into the selected duct using fluoroscopic guidance. A Longdwell needle (e.g., Ring) could also be used. Tenting of the contrast in the targeted duct signifies duct entry. The 1st needle ⇨ remains in place so that additional contrast can be injected if needed.* **(Right)** *A 0.035" 3-J guidewire ↪ is advanced through the 19-g needle → into the duct ↬. The guidewire has passed through the stricture ⇨ into bowel ⇢. The initial access ⇰ has been preserved.*

Step-by-Step: PTBD (Biliary Drain Placement)



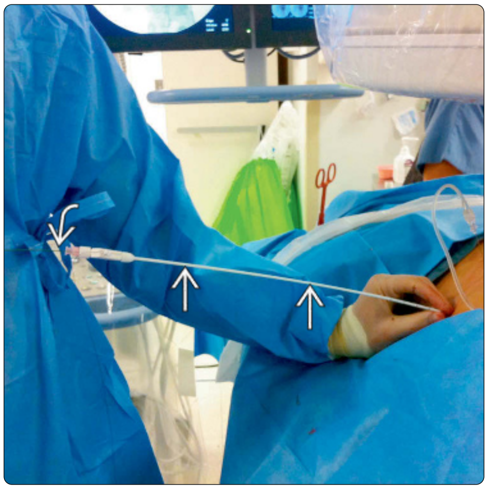
Step-by-Step: PTBD (Biliary Drain Placement)



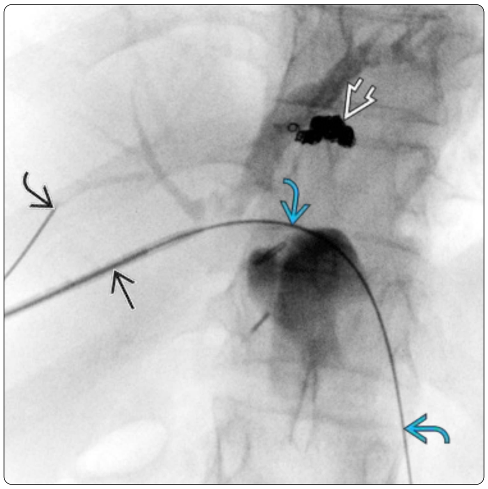
(Left) *The 19-g needle is removed, and a 5-Fr Kumpe catheter → is advanced over the guidewire ↪ into the bowel. This permits exchange of the 3-J guidewire for a stiff 0.035" Amplatz guidewire. If the stricture had not been initially crossed with the 3-J guidewire, a combination of a hydrophilic guidewire and a Kumpe catheter could have been used to negotiate the stricture.* **(Right)** *After placement of the Amplatz guidewire ⇢, the Kumpe catheter is removed and the soft tissue tract is dilated with an 8-Fr fascial dilator →.*

(Left) *An 8-Fr pigtail drainage catheter → with an inner stiffening cannula is advanced over the wire ↪ into the bile duct.* **(Right)** *Corresponding fluoroscopic image shows that the drainage catheter →, loaded onto an inner stiffening cannula, is advanced over the guidewire ↪ into the chosen biliary duct. Note that the primary access ↪ has still been preserved, which is helpful if the secondary access is lost for any reason. Also note that there are embolization coils ⇨ in the left lobe from treatment of prior hepatic injury.*

Step-by-Step: PTBD (Biliary Drain Placement)

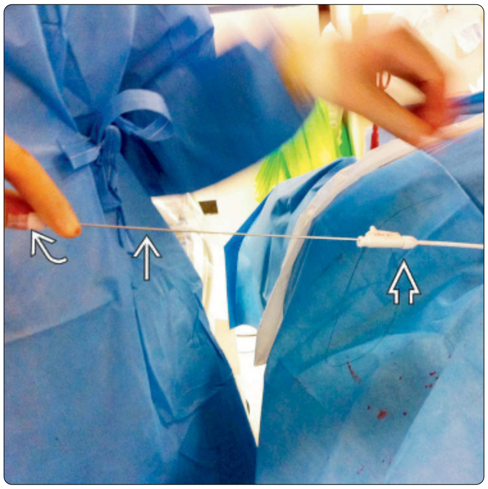


Step-by-Step: PTBD (Biliary Drain Placement)

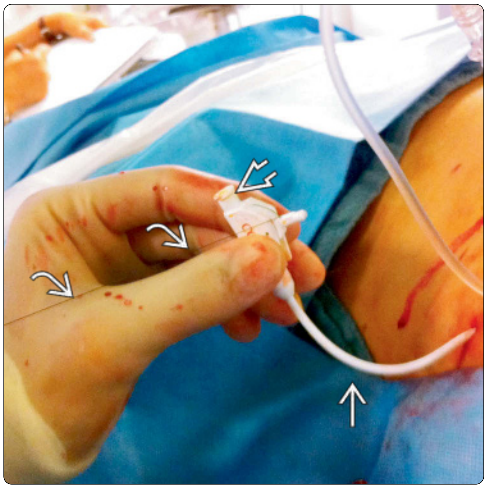


(Left) *Once the drainage catheter is in the biliary duct, the Luer lock of the inner cannula → is unscrewed ↪ from the catheter and is held stationary. The drainage catheter ⇨ is then advanced off of the cannula along the guidewire using fluoroscopic monitoring.* **(Right)** *The guidewire and inner cannula are removed, and the pigtail portion of the drainage catheter → is formed by pulling on the locking suture ↪. The external hub ⇨ of the catheter will be subsequently connected to a 3-way stopcock and drainage bag.*

Step-by-Step: PTBD (Biliary Drain Placement)

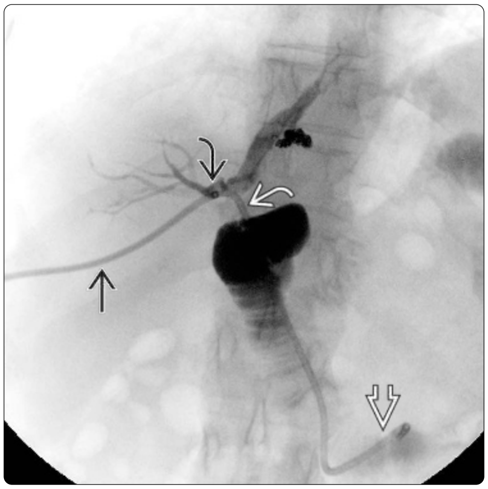


Step-by-Step: PTBD (Biliary Drain Placement)

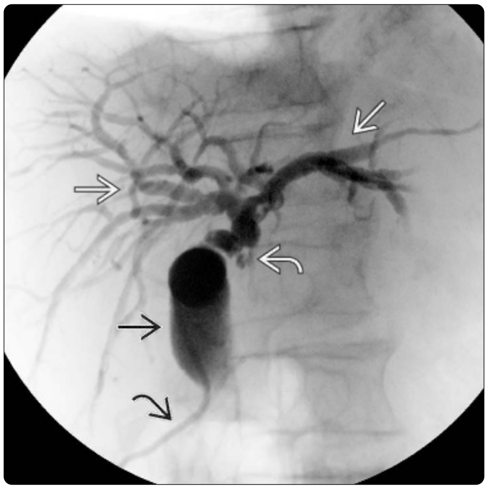


(Left) *Contrast injection of the internal/external drainage catheter → confirms traversal of the stricture ↪, with the pigtail tip ⇨ in the bowel. A radiopaque ring ↪ demarcates the most proximal sidehole, which is within the duct.* **(Right)** *Contrast injection of an indwelling cholecystostomy tube ↪ demonstrates the gallbladder →, dilated intrahepatic bile ducts →, and a common bile duct stricture ↪. Percutaneous transhepatic biliary drainage was subsequently performed through a 2nd access.*

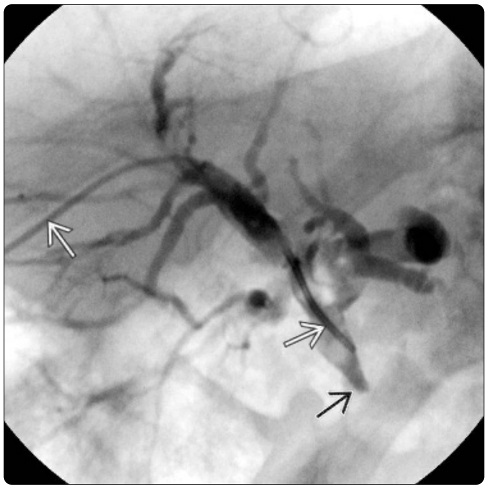
Step-by-Step: PTBD (Final Drainage Catheter Position)



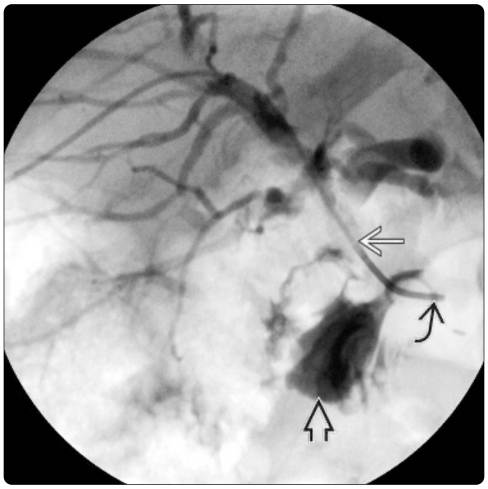
Cholangiography via Cholecystostomy



Dilation of Biliary Stricture (Imaging Prior to Crossing Lesion)

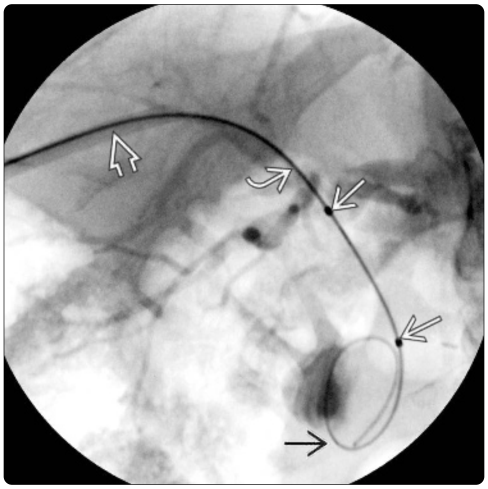


Dilation of Biliary Stricture (Catheter Crossing Lesion)

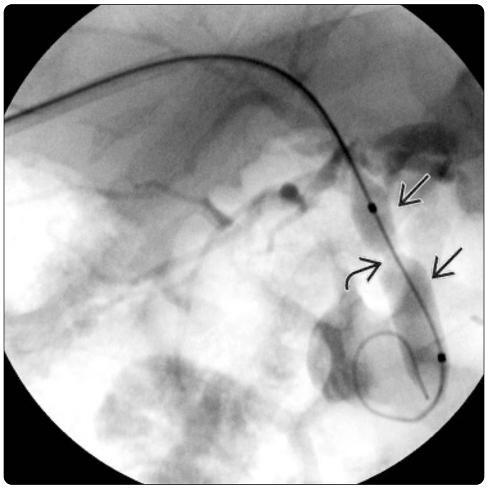


(Left) *Spot radiograph from a 62-year-old man with a history of a prior Whipple procedure for pancreatic acinar cell carcinoma and new onset of jaundice shows contrast injection of a 5-Fr Kumpe catheter* ➡ *that had been introduced via a transhepatic approach. Contrast demarcates the proximal extent of an anastomotic stricture* ⇨*.* **(Right)** *The Kumpe catheter* ⇨ *has been advanced through the stricture into the bowel* ⇨*, where a repeat contrast injection shows the distal extent* ➡ *of the stricture.*

Dilation of Biliary Stricture (Angioplasty Balloon Placement)

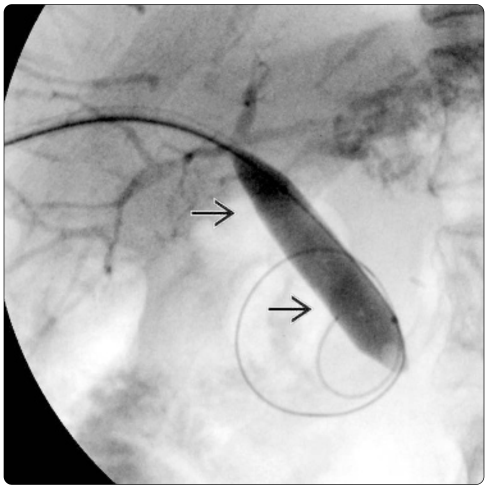


Dilation of Biliary Stricture (Angioplasty Balloon Inflation)

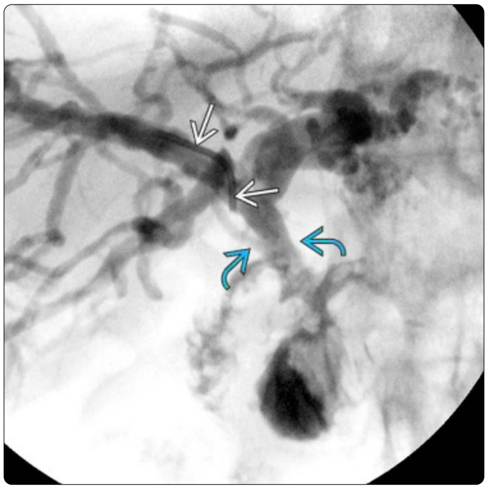


(Left) *Balloon angioplasty catheter* ➡ *was introduced over an Amplatz guidewire* ⇨ *via an access sheath* ➡ *& advanced to the level of the stricture. Radiopaque markers* ➡ *demarcating the proximal & distal extent of the deflated balloon are positioned to encompass the stricture.* **(Right)** *The balloon* ⇨ *is inflated with contrast. A "waist"* ⇨ *in the balloon corresponds to the stricture. Occasionally, the balloon may propel forward into the bowel during inflation; counter-traction on the catheter may be necessary.*

Dilation of Biliary Stricture (Angioplasty Balloon Inflation)



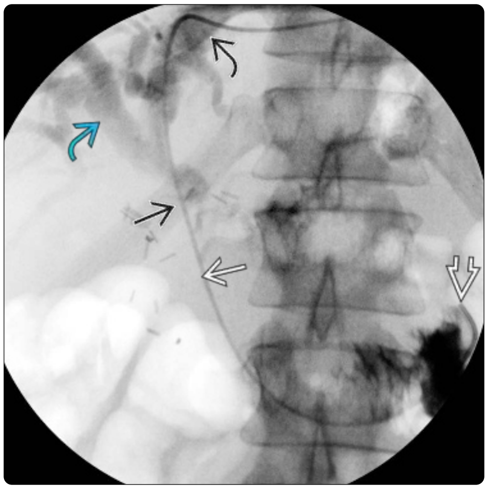
Dilation of Biliary Stricture (Appearance After Angioplasty)



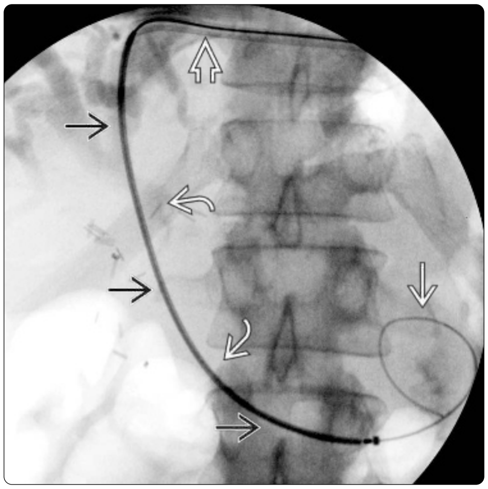
(Left) *The balloon* ⇨ *is inflated further and the "waist" is obliterated. The inflation is maintained for 1 minute. The balloon is then deflated and the process is repeated for a total of 3 dilatations. Algorithms differ among interventionalists; in one frequently used algorithm, 3 treatment sessions are employed, each 1-2 weeks apart.* **(Right)** *Contrast injection via a Kumpe catheter* ➡*, performed after 3 individual dilatation sessions, shows improvement in the stricture* ⇨*. Afterward, the Kumpe catheter was removed.*

(Left) *Percutaneous transhepatic biliary access has been achieved via the left system ↪. A 5-Fr Kumpe catheter → has traversed a common duct stricture ⇨, with the catheter tip ⇨ in the bowel. Intrahepatic ductal dilatation ↪ is seen.* **(Right)** *A catheter carrying a Wallstent ⇨ is introduced through a sheath ⇨ and is advanced over an Amplatz guidewire →. The Wallstent is positioned to encompass the entire length of the stricture ↪, with the ends of the stent extending at least 2-3 cm proximal and distal to the stricture margins.*

Percutaneous Biliary Stent Placement (Initial Access Into Biliary System)

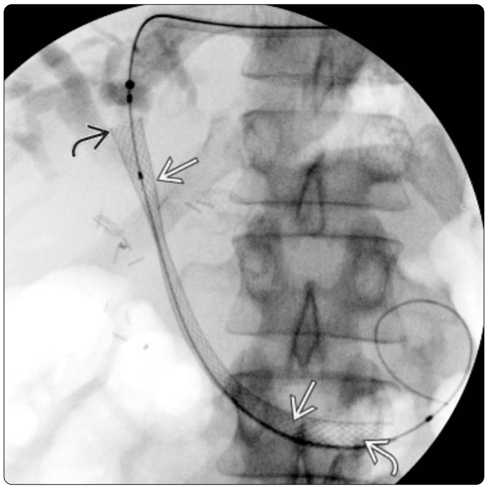


Percutaneous Biliary Stent Placement (Introduction of Self-Expanding Stent)

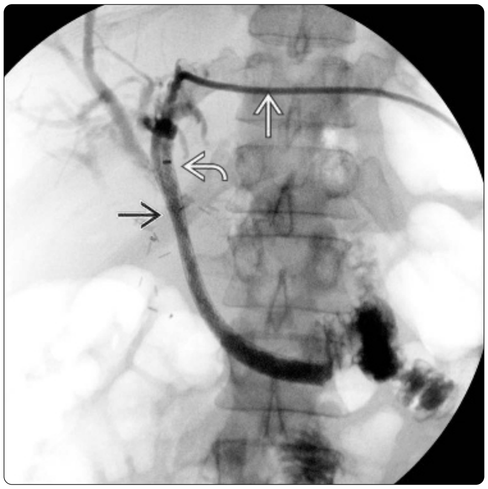


(Left) *Spot radiograph shows the Wallstent → has been deployed. Note the distal tip ↪ is in the bowel and the proximal tip ↪ is within intrahepatic ducts. It is important the stent extends proximal and distal to the stricture, as the stent will shorten as it expands.* **(Right)** *A safety catheter → is placed just into the stent ⇨; the radiopaque marker ↪ of the catheter tip ends within the stent lumen. Contrast injection confirms stent position and patency.*

Percutaneous Biliary Stent Placement (Self-Expanding Stent Deployment)

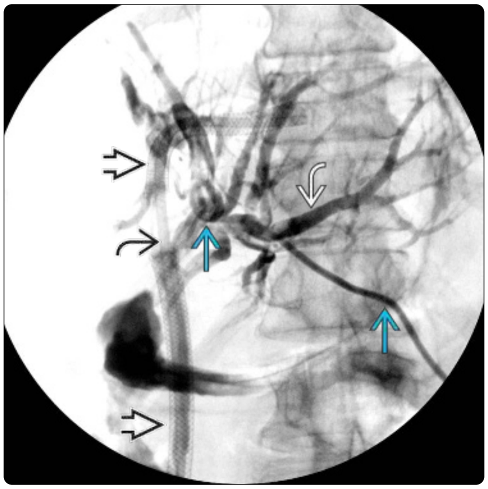


Percutaneous Biliary Stent Placement (Final Stent Position by Cholangiography)

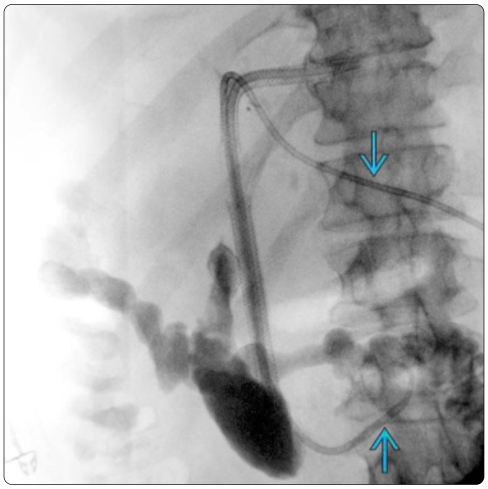


(Left) *Radiograph in a patient with a prior right hepatectomy and hemobilia shows an 8-Fr drainage catheter ⇨ has been placed into a dilated segment III duct ↪. Metallic stents ⇨ and 1 plastic stent ↪, previously placed endoscopically, extend into the segment II duct, thus compromising drainage of the segment III duct. Filling defects from hemobilia are present in the bile ducts.* **(Right)** *Several days later, the initially placed external drainage catheter is converted to an internal/external drainage catheter ⇨.*

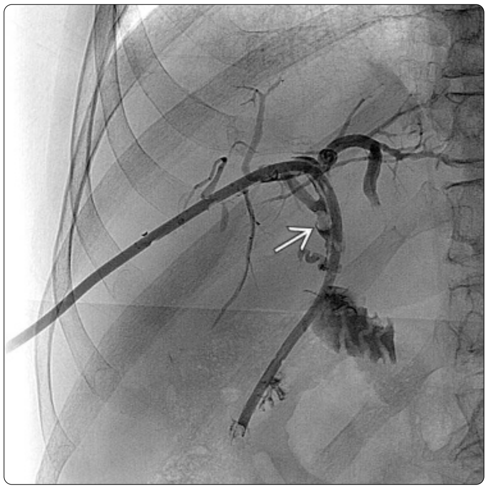
PTBD: Left-Sided External Catheter (Cholangiogram)



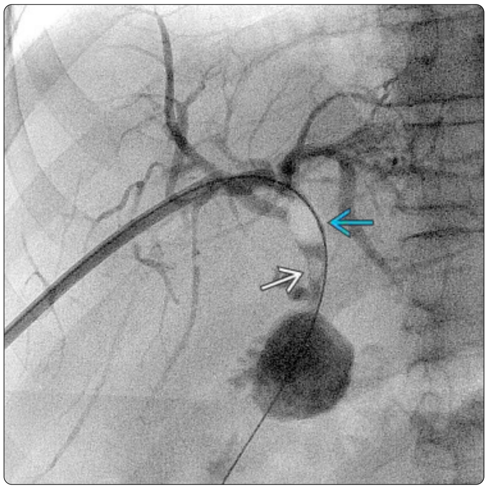
PTBD: Left-Sided External Catheter (Conversion to Internal/External)



Percutaneous Stone Removal (Initial Cholangiogram)

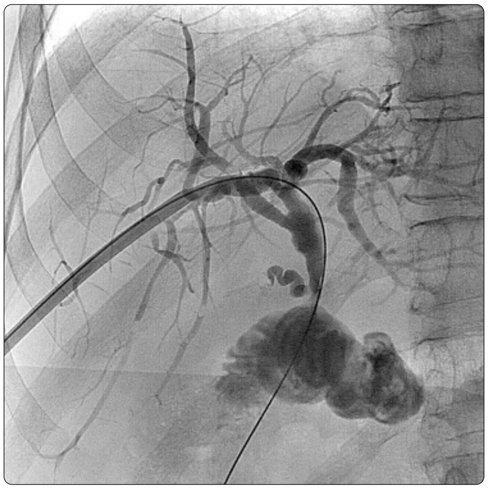


Percutaneous Stone Removal (Balloon Sweep of CBD)

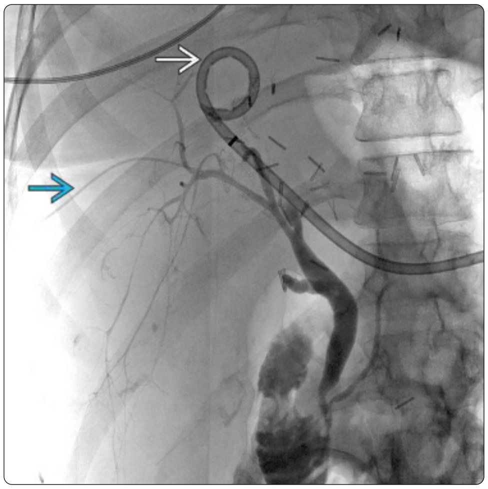


(Left) *A spot radiograph from a tube cholangiogram demonstrates a round filling defect* ➡ *in the CBD, consistent with a biliary stone.* **(Right)** *Single fluoroscopic image demonstrates an inflated Fogarty balloon* ⇨*, within the CBD, proximal to the biliary stone* ➡*. The Fogarty balloon is then advanced into the small bowel, pushing the stone out of the CBD.*

Percutaneous Stone Removal (Final Cholangiogram)

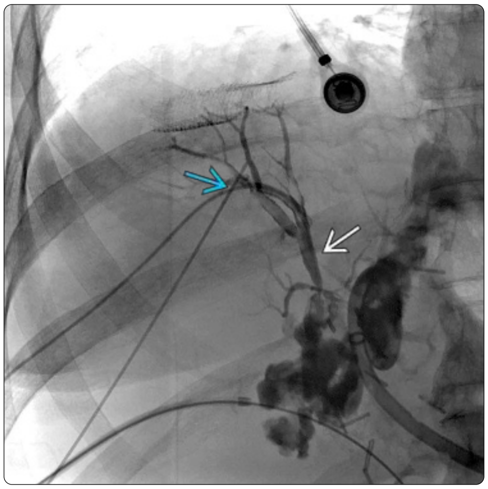


ESBDL (Initial Cholangiogram)

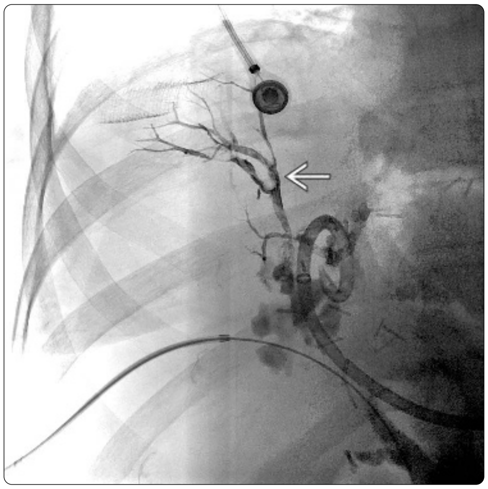


(Left) *Spot fluoroscopic image following stone removal into the small bowel demonstrates resolution of the filing defect seen at the start of the procedure.* **(Right)** *This 54-year-old woman underwent extended left hepatectomy complicated by a large intraperitoneal bile leak for months. A percutaneous drain* ➡ *within the bile leak is extrahepatic. PTC* ⇨ *shows no leak; however, multiple right hepatic bile ducts are missing superiorly.*

ESBDL (Access into Excluded Biliary System)



ESBDL (Embolization of Excluded Biliary System)



(Left) *Contrast injection via the percutaneous drain highlights the extrahepatic space. More forceful injection resulted in retrograde flow into an ESBDL from segments 5/8* ➡*. This enabled percutaneous access into the excluded biliary system* ⇨*.* **(Right)** *Surgical options were considered, and fibrin gluing of the cut liver edge did not stop the leak. A combination of Onyx and glue were deployed into the ESBDL* ➡ *(staged over multiple procedures), halting the leak. Follow-up CT revealed atrophy of the ESBDL segments.*

Cholecystostomy

KEY FACTS

TERMINOLOGY

- **Percutaneous cholecystostomy**: Image-guided placement of catheter into gallbladder (GB) lumen
- Indications
  - GB decompression in setting of acute calculus or acalculous cholecystitis
  - Biliary access when transhepatic route has failed

PROCEDURE

- US and fluoroscopic guidance preferred
- Transhepatic route preferred vs. transperitoneal, unless severe bleeding diathesis is present
- Seldinger technique is typically preferred
  - Guide 18-g needle into GB lumen under direct visualization (US or CT)
  - Advance stiff 0.035" guidewire though needle, coiling it in GB lumen
  - Advance drainage catheter over wire
  - Confirm position within GB lumen
- Trocar technique can be used
  - Assemble drain over stiff cannula with sharp trocar
  - Confirm that tip is well within GB using US visualization

POST PROCEDURE

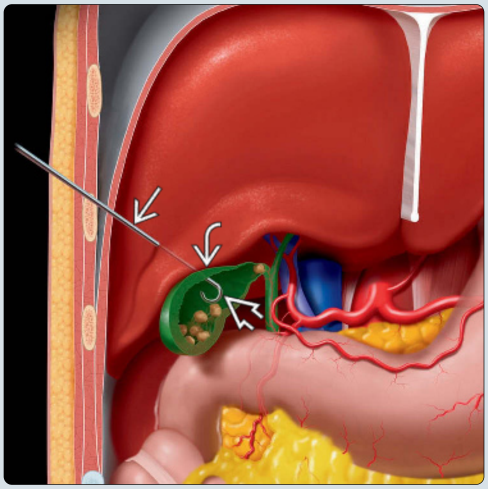
- Maintain cholecystostomy tube and follow up laboratory results of aspirated bile
- Drain removal
  - No cholelithiasis
  - Mature tract (4-6 weeks after placement)
  - Interval cholecystectomy (removed during surgery)

OUTCOMES

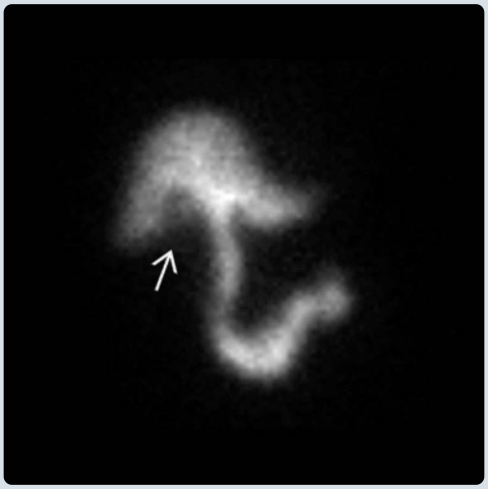
- Relatively low-risk procedure with few absolute contraindications
- Most significant complications
  - Bowel perforation
  - Bile leak or peritonitis
  - Hemorrhage

(Left) *Graphic shows a cholecystostomy catheter* ➡ *that has been percutaneously placed via a transhepatic approach, traversing the bare area* ➡ *of the gallbladder (GB), with the pigtail loop* ➡ *within the GB lumen.* **(Right)** *Hepatobiliary scan (HIDA) reveals no uptake of radiotracer in the GB. This was confirmed on 4-hour delayed imaging and is in keeping with acute cholecystitis. A rim of decreased activity in the hepatic parenchyma* ➡ *is suggestive of pericholecystic inflammation.*

Percutaneous Transhepatic Access

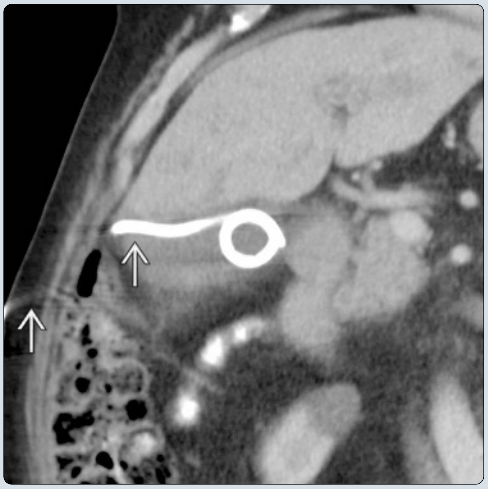


Hepatobiliary Scan (HIDA)

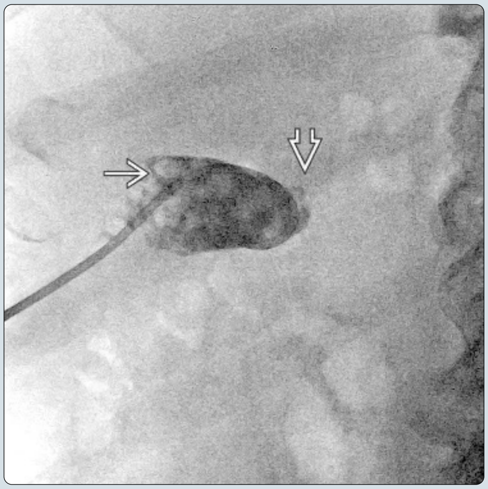


(Left) *Oblique coronal CT reconstruction demonstrates the path* ➡ *of a percutaneous transhepatic cholecystostomy tube. The inferior liver edge is visible inferior to the tube.* **(Right)** *Injection of contrast through a cholecystostomy tube demonstrates multiple gallstones* ➡ *and obstruction of the cystic duct* ➡*.*

Percutaneous Cholecystostomy Drain (Coronal CT)



Percutaneous Cholecystostomy Drain (Fluoroscopic Imaging)



TERMINOLOGY

Definitions

- Percutaneous cholecystostomy (PC): Image-guided placement of drainage catheter into gallbladder (GB) lumen

PREPROCEDURE

Indications

- GB decompression in setting of acute calculus or acalculous cholecystitis
  - Temporary therapy in setting of conditions preventing immediate surgical intervention (critical illness, pregnancy, etc.)
  - Definitive therapy in permanent nonsurgical candidates (chronic illness, palliative care, etc.)
  - Definitive therapy for acute acalculous cholecystitis
- Biliary access when transhepatic route has failed

Contraindications

- Absolute: Uncorrectable coagulopathy
- Relative
  - Extensive cholelithiasis or porcelain GB (may preclude access or formation of drain)
  - GB tumor (tube may result in tumor seeding)

Preprocedure Imaging

- Confirm diagnosis of cholecystitis
  - US or CT findings
    - GB distention
    - GB wall thickening
    - Pericholecystic fluid
    - Gallstones
    - Positive Murphy sign (US)
  - Cholescintigraphy (radionuclide or HIDA scan)
    - Nonvisualization of GB after 3-4 hours or 30 minutes after morphine administration

Getting Started

- Things to check
  - Clinical history and physical examination
  - Labs: Procedure has moderate risk of bleeding
    - INR recommended, correct to < 1.5
    - Platelets not routinely recommended, but transfuse if count know to be < 50 K/uL
    - Partial thromboplastin time recommended for patients receiving heparin
  - Medications: Anticoagulants, antibiotics (consider gram-negative prophylaxis if not already being administered)
  - Allergies: Iodinated contrast material, antibiotics, local anesthetics, adhesives/latex
- Medications
  - Anesthesia
    - 1% lidocaine local anesthetic
    - Moderate conscious sedation: Fentanyl and midazolam commonly used
    - Critically ill patients may be sedated and intubated
  - Antibiotics: Gram-negative coverage according to institutional best practice recommendations
- Equipment list
  - Skin preparatory solution and sterile drape
  - Seldinger technique
    - 18-g needle of appropriate length
    - 0.035" stiff guidewire (e.g., Amplatz or Rosen)
    - #11 scalpel
    - Stiff dilators (8-10 Fr)
    - 8- or 10-Fr locking pigtail drainage catheter
    - Drainage bag
  - Trocar technique
    - 8- or 10-Fr locking pigtail drainage catheter loaded over trocar
  - Hemostat, nonabsorbable suture, syringes, 25-g needle for local anesthesia
  - US: 2- to 5-MHz transducer, sterile cover and gel, needle guide (optional)
  - Fluoroscopy: Angiography suite or C-Arm
- Guidance choice
  - US and fluoroscopic guidance is preferred technique
  - US only (no fluoroscopy) at bedside for critically ill patients
  - CT can be considered if extensive cholelithiasis, porcelain GB, or large body habitus

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Transhepatic is preferred method
    - Can avoid entering peritoneum (drain tract through anatomic bare area) and avoid bile peritonitis
    - Extraperitoneal route helps secure GB during access and maintain drainage catheter in GB lumen
    - Subcostal access in midaxillary to midclavicular line, through avascular portion of inferior right hepatic lobe into GB
    - Avoid any interposed bowel
    - Intercostal or transdiaphragmatic route can be taken but may cause postprocedural discomfort or contamination of pleural space
  - Transperitoneal infrahepatic
    - Preferred if patient has bleeding disorder, liver disease, or if large tract (for gallstone removal/lithotripsy) planned
    - Access from anterior or anterolateral approach
    - Avoid any interposed bowel
- Position patient on fluoroscopy table or on bed: Supine or left lateral decubitus

Procedure Steps

- **General**
  - Obtain informed consent and perform time out per institutional guidelines
  - Perform preliminary scanning and mark entry site
  - Prepare surgical field per institutional guidelines
  - Anesthetize anticipated tract with 1% lidocaine
- **Technique**
  - **Seldinger technique**
    - Preferred for stability of access into GB when fluoroscopy available, limiting inadvertent placement of drain outside GB
    - Make small dermatotomy using #11 blade and dissect subcutaneous tissues with hemostat

    - – Guide 18-g needle into GB lumen under direct visualization (US or CT)
    - – Aspirate to confirm return of bile
    - – Inject small amount of contrast if under fluoroscopy
    - – Advance stiff 0.035" guidewire though needle, coiling it in GB lumen
    - – Remove needle and dilate tract with sequentially larger dilators, until desired tube size reached
    - – Place drainage catheter
        - ☐ Remove dilator and advance chosen pigtail drainage catheter (usually 8 or 10 Fr) with inner stiff cannula over wire just into GB lumen
        - ☐ Unscrew inner cannula and advance drainage catheter into GB lumen under fluoroscopy (if available)
        - ☐ Remove inner cannula and wire
        - ☐ Confirm position within GB lumen with contrast injection under fluoroscopy (if available) or with US
        - ☐ Lock pigtail drainage catheter according to manufacturer's instructions
  - ○ **Trocar technique**
    - – Suitable particularly at bedside when imaging guidance is limited, and decreased number of steps/equipment needed is desirable
    - – Make adequate dermatotomy and dissect superficial tissues with hemostat
    - – Assemble drain over stiff cannula with sharp trocar
    - – Under US guidance, advance chosen pigtail drainage catheter into GB lumen
    - – Confirm that tip is well within GB using US visualization
    - – Unscrew sharp trocar and remove it
    - – Aspirate through stiff cannula
        - ☐ If bile is freely returned, advance drain
        - ☐ If bile cannot be aspirated, confirm position of drain tip and reposition as needed
    - – Lock pigtail drainage catheter according to manufacturer's instructions
    - – Confirm position of pigtail within GB lumen: US visualization, aspiration of bile
  - ○ Use care not to overdistend GB during contrast injection or wire manipulation
  - ○ Collect sample of bile for laboratory analysis
  - ○ Secure drain to skin with nonabsorbable suture
  - ○ Dress catheter site per institutional guidelines
  - ○ Drain attached to dependent drainage bag and left open until removal considered

Findings and Reporting

- Document location of catheter in GB lumen and presence/absence of gallstones, level of obstruction, physical description of aspirated bile

POST PROCEDURE

Things to Do

- Short term
  - ○ Flush catheter with 10 mL normal saline every 8-12 hours: 5 mL toward GB and 5 mL toward drainage bag via 3-way stopcock
  - ○ Record drainage daily
  - ○ Replace lost electrolytes from biliary drainage
  - ○ Follow up laboratory results of aspirated bile
- Long term
  - ○ Acalculous cholecystitis
    - – Consider drain removal after illness has passed
    - – Consider 48-hour capping trial prior to removal
  - ○ Drain should be exchanged every 4-8 weeks if long-term decompression indicated
- Drain removal
  - ○ Requirements for removal: Clinical improvement, no cholelithiasis, mature tract (4-6 weeks after placement)
  - ○ Inject small amount of contrast through drain
    - – Confirm absence of cholelithiasis
    - – Confirm contrast flow though cystic duct, common bile duct, and into bowel
    - – Evaluate for GB perforation/leak
  - ○ Unlock drainage catheter according to manufacturer's recommendations
  - ○ Remove drain with gentle manual traction and confirm complete removal with visual inspection and fluoroscopy
  - ○ Tractogram/sinogram can be performed if tract maturity is questionable
    - – Remove drain over guidewire, leaving wire coiled in GB
    - – Insert tip of vascular sheath into skin entry site
    - – Inject contrast, observe opacification of tract
    - – If leak is present, reinsert drain over guidewire to prevent bile peritonitis, biloma
    - – If no leak, remove sheath and wire

OUTCOMES

Complications

- Most feared complication(s)
  - ○ Bowel perforation: Can be avoided with careful planning
  - ○ Hemorrhage: Injury to hepatic vasculature that may require transcatheter embolization or surgery
- Immediate/periprocedural complication(s)
  - ○ Bile leakage is most common complication
    - – Retrograde leakage along catheter tract or from GB entry site peritoneum
    - – Usually self-limited with GB decompression
  - ○ Pneumothorax: Can be avoided by subcostal access
- Delayed complication(s)
  - ○ Catheter dislodgement
  - ○ Biloma formation: May require additional drain(s)

Expected Outcomes

- Considered relatively low-risk procedure with few absolute contraindications
- Reported complication rate (other than tube dislodgement/clogging) is < 6%

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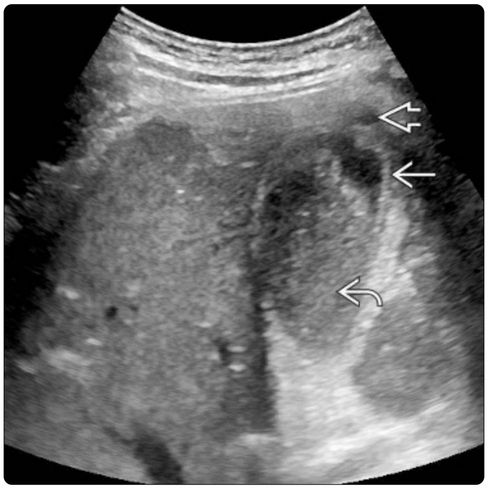
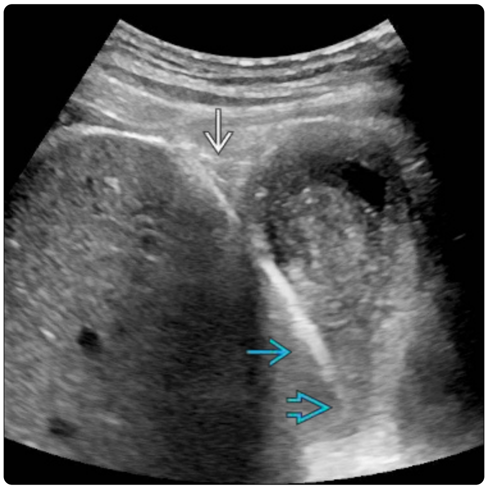
2. Popowicz A et al: Cholecystostomy as bridge to surgery and as definitive treatment or acute cholecystectomy in patients with acute cholecystitis. Gastroenterol Res Pract. 2016:3672416, 2016
3. Katabathina VS et al: Clinical presentation, imaging, and management of acute cholecystitis. Tech Vasc Interv Radiol. 18(4):256-65, 2015
4. Little MW et al: Percutaneous cholecystostomy: the radiologist's role in treating acute cholecystitis. Clin Radiol. 68(7):654-60, 2013

Cholecystostomy Drain Placement (Preprocedural US)

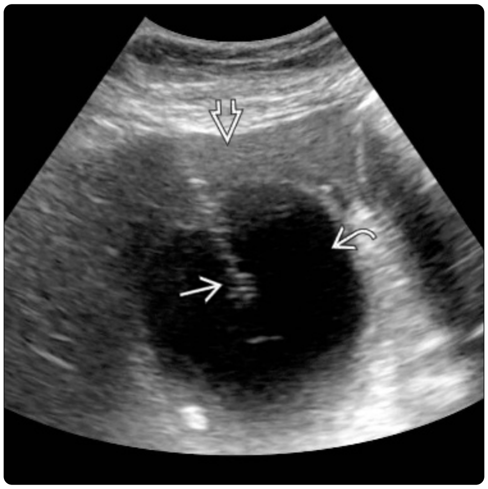


Cholecystostomy Drain Placement (US-Guided Transhepatic Access)

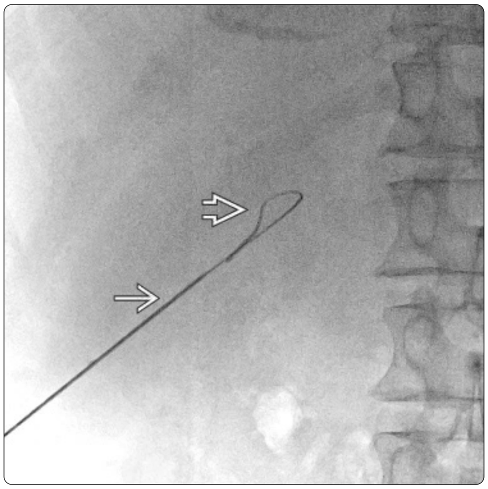


(Left) *US demonstrates findings of acute cholecystitis: Wall thickening ⇨, trace pericholecystic fluid →, and sludge in the lumen ↶. There was a positive sonographic Murphy sign.* **(Right)** *A 10-cm, 18-g trocar → is advanced percutaneously into the GB lumen via transhepatic ⇩ approach with sagittal US visualization. An 0.035" wire ⇨ can then be advanced through the trocar with US or fluoroscopic visualization.*

Cholecystostomy Drain Placement (US-Guided Transhepatic Access)

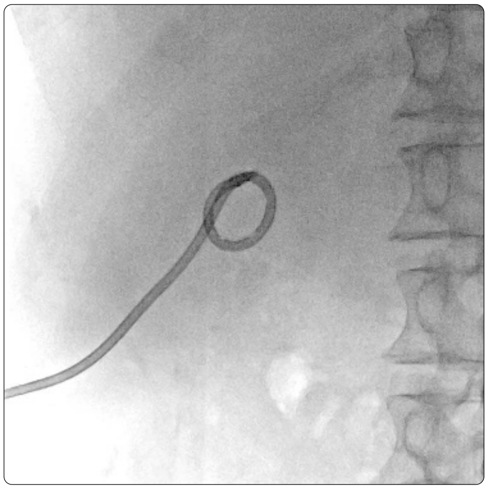


Cholecystostomy Drain Placement (Fluoroscopic-Guided Wire Advancement)

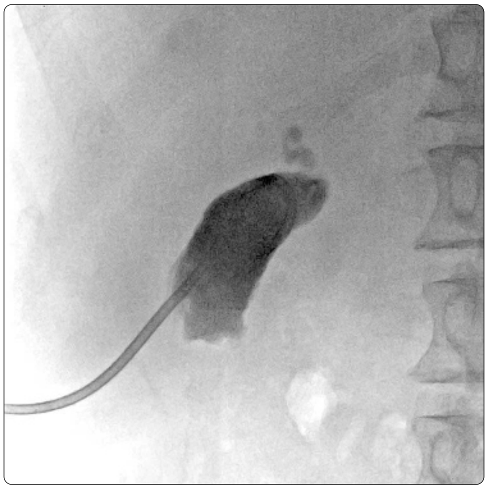


(Left) *Another example of percutaneous transhepatic access is seen in a different patient, this time with transverse visualization. The trocar → is advanced through the hepatic parenchyma ⇩ under sonographic guidance until the tip is visualized in the GB lumen ↶.* **(Right)** *Aspirate a 5-cc sample of contents for microbiology, if necessary. Contrast injected through the trocar may be performed, and minimal volume should be used. An 0.035" wire ⇨ (e.g., Amplatz, Rosen) is then advanced through the trocar →.*

Cholecystostomy Drain Placement (Fluoroscopic-Guided Drain Advancement)



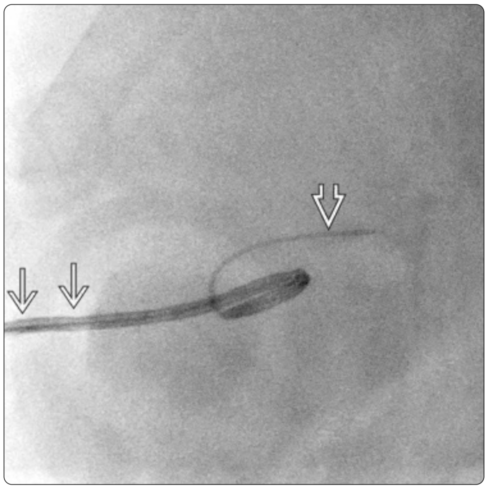
Cholecystostomy Drain Placement (Evaluation of Drain Position)



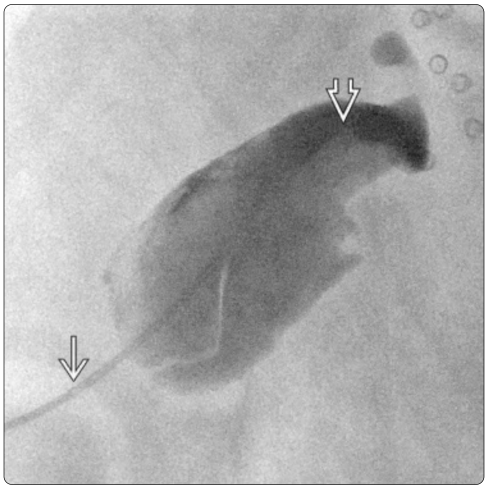
(Left) *The percutaneous tract is dilated, and a pigtail drain is then advanced over the wire and formed in the GB.* **(Right)** *Positioning of the drain is confirmed with output of bile from the drain and injection of contrast. Large-volume injections into the GB risk bacteremia as GB contents are forced into the blood stream. Evaluation of cystic duct patency can usually wait for follow-up imaging.*

(Left) *A patient with a cholecystostomy tube was complaining of leakage at the skin site. Contrast injection through the tube showed the pigtail partially uncurled, with several sideholes* ➡ *located outside of the GB. An Amplatz wire* ➡ *is advanced through existing tube into the GB, and the tube is removed.* **(Right)** *A 5-Fr Kumpe catheter* ➡ *was advanced over the wire until the tip* ➡ *was well within the GB. Catheter position was confirmed with injection of dilute contrast.*

Malpositioned Cholecystostomy Tube (Removal Over Wire)

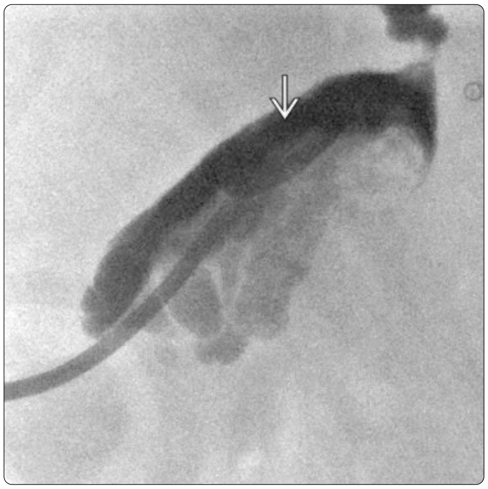


Malpositioned Cholecystostomy Tube (Wire Advancement Through Catheter)

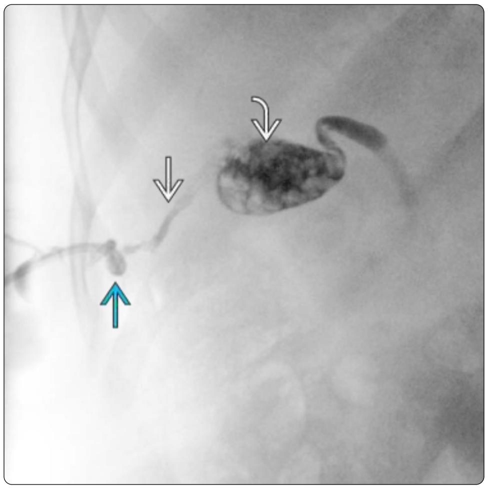


(Left) *A new pigtail cholecystostomy drain (with plastic inner cannula) was advanced over the Amplatz wire. The inner cannula and wire were then removed, and positioning of new pigtail drain* ➡ *was confirmed with contrast.* **(Right)** *Fluoroscopic spot radiograph shows the pigtail tip* ⇨ *of the dislodged cholecystostomy catheter laterally in the soft tissues outside of the liver. Contrast injected through the catheter opacifies a tract* ➡ *to the stone-filled GB* ➡*.*

Malpositioned Cholecystostomy Tube (Advancement of New Drain)

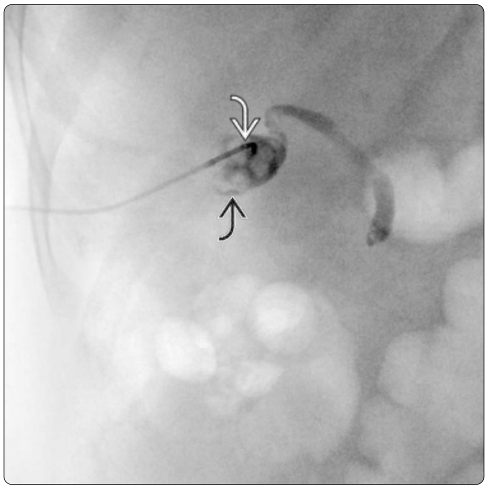


Cholecystostomy Drain Rescue (Sinogram)

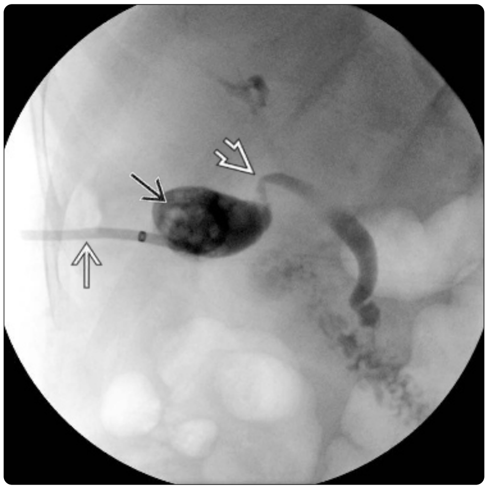


(Left) *The drain was removed over a guidewire. A hydrophilic Glidewire and a Kumpe catheter were then advanced through the original cholecystostomy catheter tract. The catheter tip* ➡*, positioned inside of the GB* ⇨*, was confirmed with contrast.* **(Right)** *The guidewire was advanced into the GB, the Kumpe catheter was removed, and a new cholecystostomy catheter drain* ➡ *was introduced over the guidewire. Note the pigtail positioned within the stone-filled GB lumen* ⇨ *and the patent cystic duct* ➡*.*

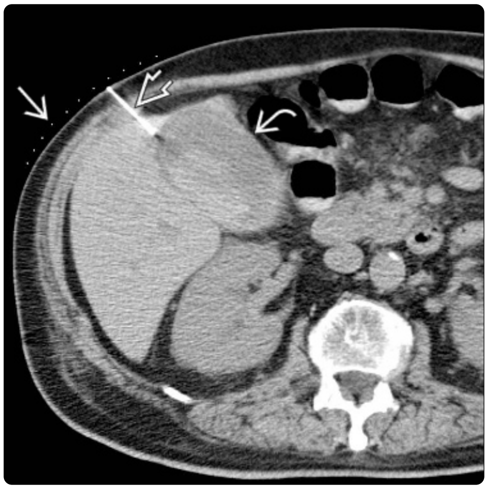
Cholecystostomy Drain Rescue (Advancement into Gallbladder)



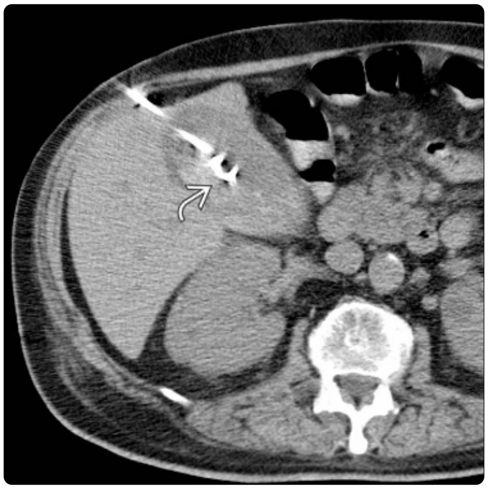
Cholecystostomy Drain Rescue (New Cholecystostomy Drain Placement)



CT-Guided Drain Placement With Complication (Transhepatic Advancement)

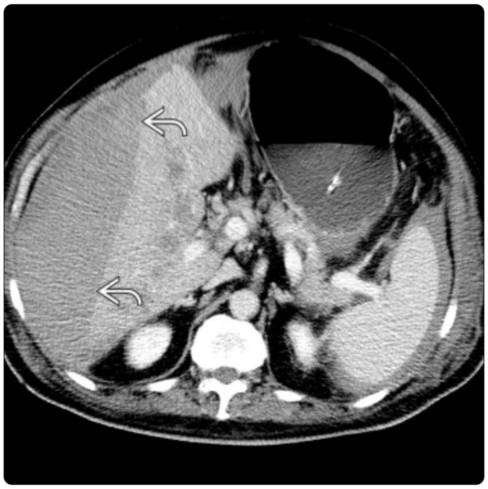


CT-Guided Drain Placement With Complication (Final Drain Position)

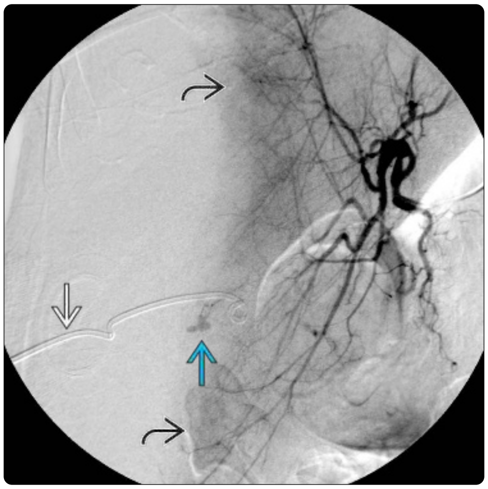


(Left) *NECT demonstrates a radiopaque grid ➔ on the skin to localize the GB ↪ and an appropriate approach. A needle ⇨ is advanced to the GB edge under CT guidance. The needle will be further advanced.* **(Right)** *The wire was advanced through the trocar and coiled within the GB. After needle removal, a dilator was advanced over the wire into the GB lumen and then exchanged for the cholecystostomy drain ↪. (Courtesy A. Thabet, MD.)*

CT-Guided Drain Placement With Complication (Postprocedural Bleed)

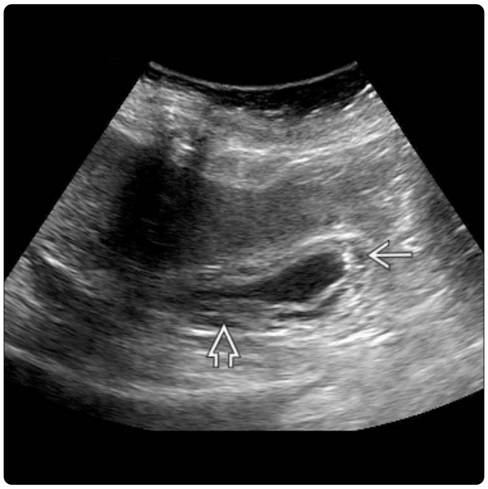


CT-Guided Drain Placement With Complication (Hepatic Angiogram)

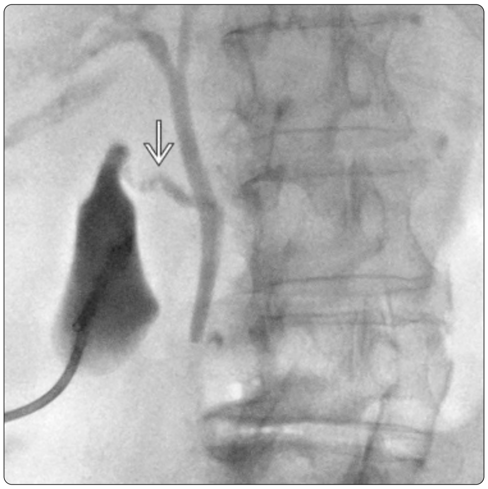


(Left) *The patient's hemoglobin level began falling. CECT demonstrates a large hepatic subcapsular hematoma ↪. The findings are consistent with active bleeding, presumed secondary to drain placement.* **(Right)** *DSA shows hepatic displacement ↪ by the subcapsular hematoma. Contrast extravasation ➔ indicates active bleeding, adjacent to the cholecystostomy catheter ⇨. Transcatheter arterial embolization was curative. (Courtesy A. Thabet, MD.)*

Acalculous Cholecystitis (Diagnostic US)



Acalculous Cholecystitis (Cholecystostogram)



(Left) *US demonstrates findings of acute cholecystitis in a patient with a severe intercurrent illness. No gallstones are present, but there is wall thickening ⇨, trace pericholecystic fluid ➔, and a positive Murphy sign. This is consistent with acalculous cholecystitis.* **(Right)** *A subsequent cholecystostogram reveals patency of the cystic duct ➔ in this same patient with acalculous cholecystitis. The patient's condition improved with GB decompression, and the tube was removed after tract was allowed to mature.*

KEY FACTS

PREPROCEDURE

- Indications
  - Urinary drainage
  - Urinary diversion
  - Percutaneous access for nephrolithotomy
  - Whitaker test: Evaluation of obstruction
- Preprocedure imaging
  - Assess degree of hydronephrosis
  - Evaluate position/anatomy of kidney

PROCEDURE

- US-guided initial access preferred
  - Avascular plane of Brödel: 20-30° off sagittal plane
- Direct fluoroscopic access via
  - Direct puncture using anatomic landmarks
  - Targeting of stone or indwelling stent
  - IV contrast ± furosemide (helpful in nondilated system)
- 1-stick technique if targeted calyx visualized/accessed at outset of procedure; otherwise, 2-stick technique

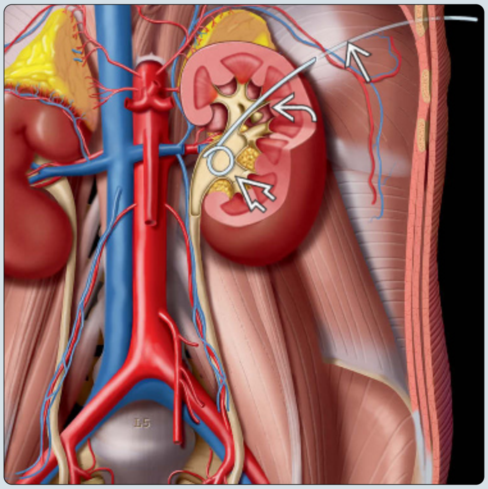
POST PROCEDURE

- Successful access into renal collecting system
  - 82-96% success in nondilated systems
  - 96-100% success in dilated systems
  - 91% into desired target identified for percutaneous intervention
- Restoration of ureteral patency after iatrogenic injury
  - Overall success rate of 78-87%
  - Comparable to surgical repair except in case of complete transection
- Transient hematuria common for 1-2 days after placement

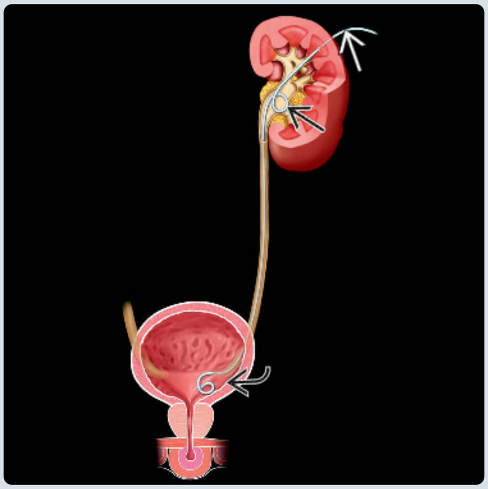
OUTCOMES

- Complications
  - Vascular injury and gross hematuria
  - Consider angiography/embolization if persists
  - Bowel transgression with suprapubic tube

Percutaneous Nephrostomy Catheter

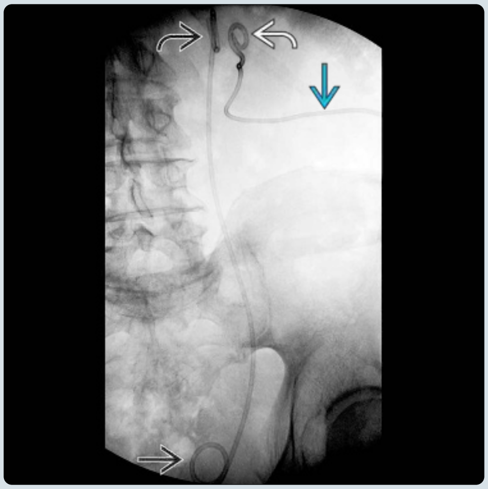


Percutaneous Nephroureteral Catheter

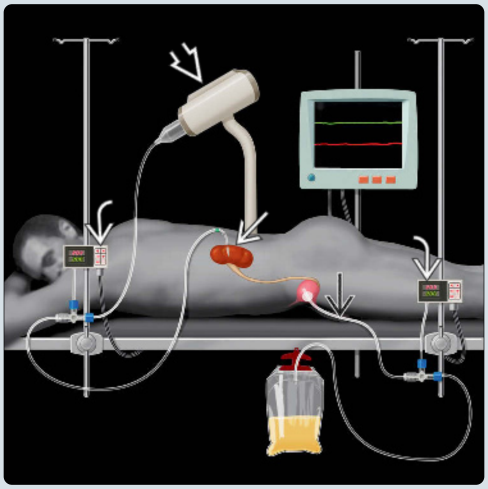


(Left) *Graphic depicts a percutaneous nephrostomy (PCN) catheter ➡ in the left renal collecting system via an upper pole calyx ↪. The pigtail is appropriately positioned within the renal pelvis ⇨.* **(Right)** *Graphic depicts a percutaneous nephroureteral (PCNU) catheter ➡ in the left renal collecting system. Proximal pigtail is in the renal pelvis →, and distal pigtail is in the bladder ⤻.*

Percutaneous Nephrostomy Catheter: Fluoroscopy



Whitaker Test: Evaluation of Ureteral Obstruction



(Left) *Spot fluoroscopy shows a PCN catheter → with pigtail in the renal pelvis ↪. An internal ureteral stent also has a proximal pigtail in the renal pelvis ⤻ plus a distal pigtail in the bladder →.* **(Right)** *Whitaker test schematic shows that a needle ➡ in the renal pelvis is infused with saline via an injector ⇨. Pressures are measured there and in the bladder via a Foley catheter →, using transducers ↪, to evaluate for ureteral stasis vs. obstruction.*

TERMINOLOGY

Definitions

- Percutaneous nephrostomy (PCN) catheter: Percutaneous catheter in renal collecting system for external drainage
- Percutaneous nephroureteral (PCNU) catheter: Percutaneous catheter in renal collecting system that extends through ureter into bladder for internal or external drainage
- Antegrade ureteral (double J) stent (AUS): Percutaneous stent extending through ureter from renal pelvis into urinary bladder for internal drainage
- Suprapubic cystostomy (SPT): Percutaneous drainage or Foley catheter entering bladder above pubic symphysis for external drainage
- Whitaker test: Invasive test used to confirm &/or identify urinary obstruction in equivocal cases via pressure measurements obtained from renal collecting system and bladder during antegrade infusion of dilute contrast

PREPROCEDURE

Indications

- PCN, PCNU, or AUS
  - Urinary drainage
    - Intrinsic or extrinsic ureteral obstruction
    - Benign or malignant etiologies
  - Urinary diversion
    - Ureteral injury (usually iatrogenic due to gynecologic surgery)
    - Fistula involving kidney, ureter, or bladder
    - Hemorrhagic cystitis
  - Percutaneous access for
    - AUS placement
    - Percutaneous nephrolithotomy
    - Biopsy or treatment of tumor
- Whitaker test: Used to evaluate for obstruction between renal pelvis and bladder in case of unexplained hydronephrosis or hydroureter
  - Gold standard, but use reserved for when noninvasive studies are equivocal
- SPT
  - Bladder outlet obstruction
  - Urinary incontinence or neurogenic bladder
  - Fistula involving bladder
  - Urethral trauma

Contraindications

- Uncorrectable coagulopathy
- In case of AUS placement
  - Untreated bladder outlet obstruction
  - Untreated urosepsis

Preprocedure Imaging

- Normal anatomy
  - Kidneys oriented 30-50° to coronal plane
  - Upper pole usually more medial than lower pole
  - Collecting system: Calyces (~ 14) drain into renal pelvis
    - Anterior calyces: Project side-on, appear cup-like
    - Posterior calyces: Project end-on, appear circular
  - Plane of Brödel
    - Lies 20-30° from sagittal plane
    - Relatively avascular plane between anterior/posterior divisions of renal artery
- Variant anatomy
  - Horseshoe, malrotated, or ptotic kidneys
  - Duplicated collecting system
- Transplant kidneys
  - Position and orientation within right or left iliac fossa
  - Location of anastomosis
- Pathology
  - Hydronephrosis or hydroureteronephrosis
  - Obstructing or suspicious mass

Getting Started

- Things to check
  - Patient history and physical
    - Procedure indications
    - Medications: Anticoagulant or antiplatelet agents
    - Allergies
    - Signs or symptoms of urosepsis
      - Preprocedure antibiotics if untreated
      - Hemodynamic support
    - Pregnancy: Consider trial of conservative management prior to intervention
  - Laboratory parameters
    - Complete blood count: Platelet > 50,000/μL
    - Coagulation profile
      - International normalized ratio ≤ 1.5
      - Normal prothrombin time, partial thromboplastin time
    - Serum electrolytes
      - Correct any renal failure-associated hyperkalemia
- Medications
  - Anesthesia
    - 1% lidocaine local anesthetic
    - Procedural sedation (if hemodynamically stable)
    - Low threshold for anesthesiology assistance due to risk of sepsis/septic shock
  - Prophylactic antibiotics
    - Specific agent based on available cultures
    - Empiric gram-negative coverage if no cultures
- Equipment list
  - **General**
    - US equipment
      - 3.5-MHz transducer
      - Sterile US probe cover and gel
    - Fluoroscopy equipment
    - CT equipment
      - Radiopaque grid
  - **PCN**
    - 21- to 22-gauge Chiba needle
    - 0.018" guidewire
    - 5- to 6-Fr coaxial dilator-sheath assembly
    - 0.035" 3-J guidewire
    - 8- to 10-Fr dilator as appropriate
    - 8- to 10-Fr locking pigtail catheter
  - **PCNU**
    - 0.035" Amplatz guidewire
    - 8-Fr, 20- to 24-cm nephroureteral catheter
  - **AUS**

    - 0.035" Amplatz guidewire
    - 8-Fr, 20- to 24-cm double pigtail (J) ureteral stent
  - **Whitaker test**
    - 18- to 22-gauge needle
    - Manometer or pressure transducer
    - Power injector/infusion pump
    - Bladder catheter (e.g., Foley)
    - 2 individual 3-way stopcocks and connecting tubing
  - **SPT**
    - Transurethral catheter if possible
      - 19-gauge needle if not possible
    - Trocar technique
      - Stiffening inner cannula
      - Sharp trocar
      - 8- to 16-Fr Foley catheter
    - Seldinger technique
      - 5-Fr Longdwell needle (20 cm)
      - 0.035" Amplatz wire
      - Sequential dilators
      - 8- to 14-Fr locking pigtail catheter

PROCEDURE

Patient Position/Location

- Best procedure approach
  - **General**
    - Shortest path that avoids vessels, viscera, pleura
    - Review prior imaging for anatomy and variants
    - Real-time imaging to evaluate structural relationships as these may change with patient position
  - **Patient position**
    - Native kidney: Prone position preferred
      - Prone-oblique (ipsilateral side up) if unable to lie prone or if pregnant
    - Transplant kidney: Supine position
  - **Needle entry**
    - Access via avascular plane of Brödel: Requires positioning 20-30° off sagittal plane
      - Native: Posterior approach preferred
      - Transplant: Consider lateral approach to reduce risk of transperitoneal puncture
    - Entry into collecting system
      - Mid or lower pole calyx preferred
      - Upper pole calyx may be needed to facilitate endoureteral interventions
      - Avoid direct puncture of renal pelvis
  - **SPT**
    - Patient in supine position
    - Midline or paramedian access above pubic symphysis
      - Avoid lateral due to inferior epigastric vessels

Procedure Steps

- **General**
  - Choose imaging modality
    - US
      - Preferred modality: Real time, low cost, no radiation
      - Especially effective when hydronephrosis present
    - Fluoroscopy
      - Useful in cases of failed US-guided attempt, nondilated collecting system, or existing radiopaque target (e.g., stent, stone)
      - May require direct puncture of collecting system or instillation of IV contrast
    - CT
      - Rarely used; reserved for complicated cases, such as renal anatomic variants or severe kyphoscoliosis
  - Preprocedure imaging to identify target and access path
  - Sterilely prep skin and drape field
  - Administer 1% lidocaine at skin site and along desired tract
  - Skin nick with #11 blade
- **Initial access of renal collecting system**
  - 1-stick technique
    - Advance 21- to 22-gauge Chiba needle into calyx
      - US: Real-time direct visualization
      - Fluoroscopy (unenhanced): Use anatomic landmarks identified or existing radiopaque target
      - Fluoroscopy (enhanced): Perform intravenous pyelogram via administration of IV contrast and furosemide to opacity collecting system
    - Remove stylet and aspirate urine through needle to confirm access of collecting system
      - Aspirate enough urine such that contrast can then be instilled without overdistending system
      - Do not fully decompress system; distension makes subsequent steps easier
      - Collect sample for laboratory analysis and culture
    - Perform antegrade nephrogram to identify specific location within collecting system
      - Desired location: Proceed with PCN placement
      - Undesired location: Transition to 2-stick technique
  - 2-stick technique
    - Perform antegrade nephrogram through 1st stick
    - Identify appropriate target path for 2nd stick access, which will eventually be used for PCN placement
      - Rotate C-arm as needed to triangulate position of desired calyx via orthogonal imaging planes
    - Prepare skin site for 2nd stick access
      - Administer 1% lidocaine into skin and tract
      - Skin nick with #11 blade scalpel
    - Advance 21- to 22-gauge Chiba needle in same manner
      - May use US or fluoroscopic guidance as appropriate
    - Perform antegrade nephrogram through 2nd stick to identify specific location within collecting system
      - Desired location: Proceed with PCN placement
      - Undesired location: Repeat 2nd stick technique using either existing stick as guide
- **PCN catheter placement**
  - Introduce 0.018" guidewire into renal collecting system using fluoroscopic guidance
    - Transition between "floppy" and "stiff" part of wire is easily identified fluoroscopically
    - Advance until "stiff" part is with collecting system
  - Exchange needle for 5- to 6-Fr dilator-sheath assembly
    - Advance sheath over guidewire into collecting system
    - Remove guidewire and dilator
  - Place 0.035" 3-J wire in renal collecting system via sheath

    - Advance wire into ureter (preferred) or distal pelvis
      - Exchange sheath for 5-Fr directional catheter if needed to negotiate distal position of wire
    - If unable to advance distally, coil wire in renal pelvis
  - Dilate tract to 1-Fr size > drain size
  - Load pigtail locking nephrostomy catheter onto stiffener
  - Advance nephrostomy catheter with stiffener over wire into collecting system
    - Unscrew stiffener once within collecting system or when wire turn is reached
    - Immobilize wire and stiffener
    - Advance nephrostomy catheter off of stiffener further into collecting system
  - Remove wire and stiffener
  - Pull string to form/lock nephrostomy pigtail
    - Gently retract catheter as needed until pigtail is positioned within renal pelvis
  - Inject contrast via catheter to confirm position
  - Secure catheter at skin site
- **PCNU catheter placement**
  - Initial access of renal collecting system as above
  - Place 0.035" 3-J wire in renal collecting system via 5-Fr sheath and advance through ureter
    - If unable to access ureter
      - Exchange sheath for 5-Fr directional catheter to help negotiate position into ureter
    - If unable to cross area of stenosis
      - Exchange for hydrophilic guidewire
  - Exchange 5-Fr sheath for 5-Fr catheter and advance into bladder over wire
    - If unable to cross area of stricture/stenosis
      - Use peel-away sheath to reduce friction
      - Dilate ureter with dilator 0.5- to 1.0-Fr size > anticipated catheter
      - Perform balloon ureteroplasty
    - If still unable to pass area of stricture/stenosis, nephrostomy catheter must be placed
      - Can attempt to place ureteral stent or convert to PCNU later when inflammation improves or cause of obstruction resolves
  - Remove guidewire and perform contrast injection to confirm catheter location within bladder
  - Advance 0.035" Amplatz guidewire into urinary bladder
    - Stability of stiffer Amplatz guidewire required for placement of nephroureteral catheter
  - With Amplatz coiled in bladder, remove catheter
  - Choose appropriate nephroureteral catheter
    - 8- to 10-Fr catheters with 2 pigtails
      - Distal pigtail will coil in urinary bladder
      - Proximal pigtail will coil in renal pelvis
    - Distance between pigtails varies between catheters
      - Typically 20-28 cm
      - May estimate length needed based on patient height or measure with guidewire
  - Dilate subcutaneous tract as needed
  - Load catheter onto stiffening cannula and advance system over guidewire into urinary bladder
    - Retract wire until it is just within tip of catheter
    - Unscrew inner cannula at hub
  - Slowly withdraw guidewire and inner cannula
    - Distal pigtail will form freely in urinary bladder
  - Pull string to form/lock proximal pigtail
    - Gently retract catheter as needed until proximal pigtail is positioned within renal pelvis
  - Inject contrast to confirm position
  - Secure catheter at skin site
- **AUS placement**
  - Initial collecting system access as with PCNU placement until Amplatz wire extends to bladder
    - Can perform via existing nephrostomy catheter
  - Select ureteral stent
    - 8-Fr double pigtail (J) stent
      - Distal pigtail will coil in urinary bladder
      - Proximal pigtail will coil in renal pelvis
      - Unlike PCNU, system is completely internalized
    - Distance between pigtails varies between catheters
      - Typically 20-28 cm
      - May estimate length needed based on patient height or measure with guidewire
  - Prepare ureteral stent
    - Load stent onto stiffener
    - Attach pusher to proximal end (if not premounted on long delivery system)
  - Load stent on guidewire and advance until distal tip extends into bladder
    - Radiopaque marker on distal aspect of pusher should be in renal pelvis
  - Retract guidewire until tip is just within stent
  - Unscrew stiffener and withdraw with guidewire as unit
    - Distal pigtail will freely form in urinary bladder
  - Continue slowly retracting stiffener and wire into proximal ureter
  - Evaluate stent position
    - If too distal (i.e., proximal pigtail will be within ureter), gently retract stent over wire/stiffener
      - May need to advance wire to maintain position
    - If too proximal (i.e., proximal pigtail will be outside renal pelvis), gently advance entire system
  - Maintain wire and cannula position in proximal stent, keeping forward pressure on pusher
    - Cut and remove string connecting pusher to stent
    - Deploy stent
    - Proximal pigtail will freely form in renal pelvis
  - If temporary ("safety") nephrostomy catheter is desired, advance guidewire into renal pelvis
    - Maintain guidewire/stiffener position in renal pelvis
    - Load 8-Fr pigtail nephrostomy catheter onto stiffening cannula
    - Advance over guidewire and form pigtail in renal pelvis
- **Whitaker test**
  - Obtain access into renal collecting system
    - Through existing PCN catheter
    - Otherwise, perform as described above
      - 1-stick technique: Preferred, lower risk
      - 2-stick technique: Use 1 needle for continuous injection and other for pressure measurements
  - Insert catheter into urinary bladder and drain it
  - Attach needle/PCN to 3-way stopcock

        - Attach 3-way stopcock to pressure transducer and power injector/pump
        - Place transducer at approximate level of kidney
    - Attach Foley catheter tubing to 3-way stopcock
        - Attach 3-way stopcock to pressure transducer and to tubing for urinary drainage bag
        - Place transducer at approximate level of bladder
    - Record resting (empty) bladder and collecting system pressures by opening stopcocks to transducers
    - Begin power injection/pump of dilute contrast into needle/PCN
        - Adult flow rate: 10 mL/min
        - Small children: 5 mL/min
    - During injection of dilute contrast
        - Obtain intermittent spot fluoroscopic images
            - Monitor distention of renal pelvis and ureter
            - Identify possible points of obstruction
        - Intermittently measure pressures via both transducers
            - Pause infusion
            - Open stopcock to transducer
    - Stop injection once complete distention achieved
    - Open renal 3-way stopcock to transducer
        - Measure renal pelvis and bladder pressures every 2 min for 20 min or until they stabilize
    - Calculate gradient pressure: (Renal pelvis pressure final - baseline) - (bladder pressure final - baseline)
        - Gradient pressure < 15 cm of H_2O: Normal
        - Gradient pressure > 22 cm of H_2O: Obstruction
        - Gradient pressure of 15-22 cm of H_2O: Indeterminate
            - Increasing infusion rate to 20 mL/min may elicit abnormal gradient in such cases
    - In obstructed system, may convert access to PCN
- **SPT**
    - General
        - Distend urinary bladder with 150-500 mL of saline or dilute contrast
            - Retrograde instillation via transurethral catheter
            - Antegrade instillation via percutaneous advancement of 19-gauge needle under real-time US or CT
        - Preprocedure US to determine access and approach
        - Sterilely prep skin and drape field
        - Administer 1% lidocaine into skin and desired tract
        - Skin nick with #11 blade scalpel
    - Trocar technique
        - Perform blunt dissection at skin nick with hemostat
        - Prepare Foley catheter
            - Insert inner stiffener
            - Load onto trocar
        - Advance system into bladder under real-time US
            - Bladder wall may tent considerably
        - Remove trocar from Foley and disengage stiffener
        - Advance Foley catheter off of stiffener into bladder
        - Inflate balloon with sterile water
        - Confirm position via US or fluoroscopy
    - Seldinger technique
        - Percutaneous access of distended bladder with 5-Fr Longdwell needle (20 cm) under real-time US guidance
            - Watch for efflux of urine to confirm position
            - Inject contrast if unsure of position
        - Advance 0.035" Amplatz wire and coil in bladder
        - Dilate tract as needed
        - Advance 8- to 14-Fr locking pigtail catheter over into bladder
            - Remove wire
            - Pull back on string to form/lock pigtail
        - Confirm position via US or fluoroscopy

Findings and Reporting

- Direction of approach and location of initial access
- Findings of initial nephrogram or cystogram
    - Filling defects (e.g., renal calculi)
    - Ureteral stricture or stenosis
    - Variant anatomy (e.g., duplicated system)
- Findings of postprocedure nephrogram or cystogram
    - Size and length of catheter or stent placed
        - Include qualifier of "pigtail locking system" where appropriate to prevent inappropriate removal
    - Position of catheter/stent, including location of pigtails
    - Immediately visualized complications
- Description of urine sample and tests ordered
- Whitaker test
    - Infusion flow rate
    - Renal and bladder pressures
        - Baseline (empty) and final (distended)
        - Calculation and interpretation of pressure gradient

Alternative Procedures/Therapies

- Other
    - Retrograde ureteroscopic ureteral stent placement
    - Renal calculus removal
        - Extracorporeal shock wave lithotripsy
        - Ureteroscopic removal

POST PROCEDURE

Things to Do

- PCN or PCNU catheters
    - Flush daily with normal saline via 3-way stopcock
        - May cease regular flushing if no hematuria or clogging
    - Record output (when placed to external drainage)
    - Regular catheter exchanges
        - Prophylactic antibiotics prior to every change
        - Upsize catheter if leaking through tract
- Ureteral stents
    - If concomitant placement of safety PCN, consider clamping safety PCN next day
        - Continue clamp trial for several days
            - Unclamp PCN if flank pain or fever develop
        - Remove PCN after contrast injection shows patent stent
    - Regular retrograde stent changes by urology
- SPT
    - Regular catheter exchanges
        - Can be done at bedside once tract matures
    - May upsize catheter as needed as tract matures

Things to Avoid

- Beware access with increased risk of complication

    - Supracostal access: Pneumo-/hydro-/hemothorax/empyema
    - Direct access into infundibulum or renal pelvis: Vascular injury, hematuria, persistent urine leak
- Overlapping position of PCN and ureteral stent pigtails
    - May cause them to "link" and prevent removal of one without dislodging other

Postprocedure Imaging

- Antegrade nephrostogram
    - May not fully evaluate ureter at initial PCN placement due to sepsis/obstruction
        - Risk of aggravating sepsis from overdistention
        - Perform when clinical condition improves
    - Used to demonstrate stent patency
- Follow-up of stone disease may include
    - Plain abdominal and pelvic radiograph
    - US
    - CT (noncontrast)

OUTCOMES

Problems

- Catheter dislodgement
    - May rescue within 1-2 days if well-established tract
        - Otherwise, may require new PCN access
- Frequent clogging of PCN
    - Increase frequency of catheter flushing
    - Increase frequency of catheter exchanges
    - Upsize catheter
- Leakage around catheter
    - Exchange damaged catheters
    - Upsize catheter in case of mature tracts
    - Obtain new access if necessary

Complications

- Most feared complication(s)
    - Iatrogenic vascular injury requiring transfusion (1-4%)
        - Various vascular injuries possible
            - ☐ Pseudoaneurysm formation
            - ☐ Arteriovenous (AV) fistula
            - ☐ Arterial laceration
        - May tamponade with catheter in place
            - ☐ Venous injuries usually self-limiting
            - ☐ Small AV fistula may be self-limiting
        - Angiography and embolization if persistent
    - Visceral transgression (0.2-0.5%)
        - Colon (retrorenal or suprapubic)
        - Spleen
        - Liver
    - Pleural complications (0.1-0.6%)
        - Pneumothorax, hydrothorax, or hemothorax
- Immediate/periprocedural complication(s)
    - Transient hematuria
    - Sepsis (1-10%)
        - Higher risk in pyonephrosis
- Delayed complication(s)
    - Pseudoaneurysm with gross hematuria
- Other complications
    - Bladder irritation/pain
        - May consider cutting nephroureteral catheter so that distal tip terminates in ureter
        - May require conversion to PCN
    - Ureteral stent occlusion
        - Treat with stent exchange
    - Encrusted ureteral stent
        - Unable to remove cystoscopically
        - May require primary PCN
    - Migrated or fractured stent
        - Ureteroscopic removal
        - Percutaneous snare retrieval

Expected Outcome

- Successful access into renal collecting system
    - 82-96% in nondilated systems
    - 96-100% in dilated systems
    - 91% into specific target for percutaneous intervention
- Restoration of ureteral patency after iatrogenic injury
    - Overall success rate of 78-87%
        - Greater success (> 90%) in purely obstructive cases
        - Improved with PCNU or AUS than PCN alone
    - Comparable to surgical repair except in case of complete transection
    - Preferred initial management approach in many cases due to minimally invasive technique
- Transient hematuria common after placement
- Whitaker test: Diagnostic in 77% of cases
    - Reserve for cases equivocal on noninvasive testing

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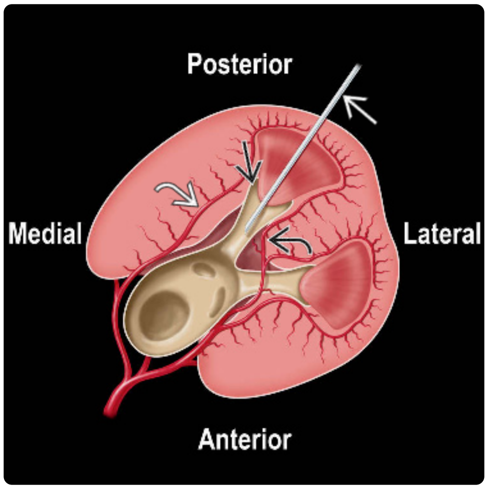
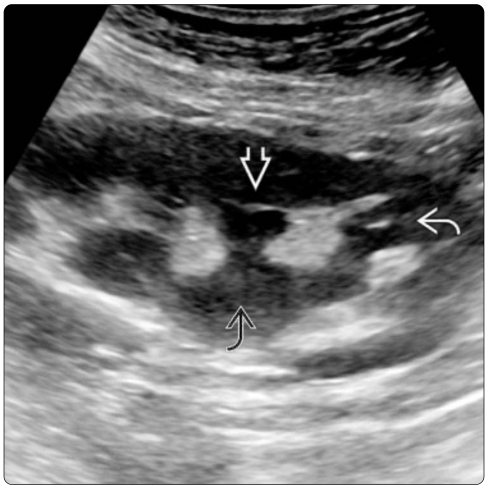
(Left) *Graphic shows a needle ➡ within a posterior calyx → along the plane of Brödel. This relatively avascular zone located between the anterior ⤷ and posterior ↪ divisions of the renal artery lies 20-30° from the sagittal plane. Access via this plane minimizes bleeding and potential vascular injury.* **(Right)** *Sagittal US of the left kidney demonstrates moderate hydronephrosis with dilatation of the calyces ⇨ and the renal pelvis ⤷. A posterior lower pole calyx ↪ is selected for PCN access.*

Preferred Needle Course: Avascular Plane of Brödel

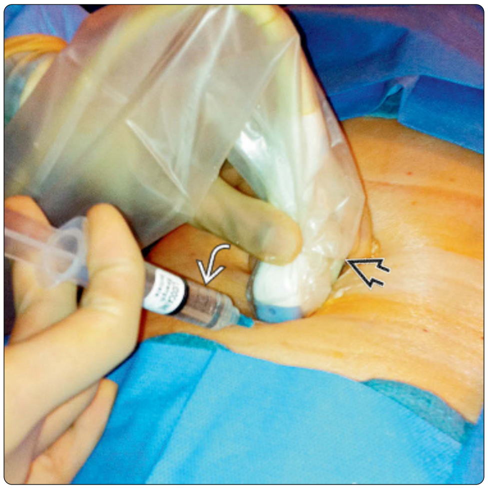


Percutaneous Nephrostomy: Preliminary US Planning

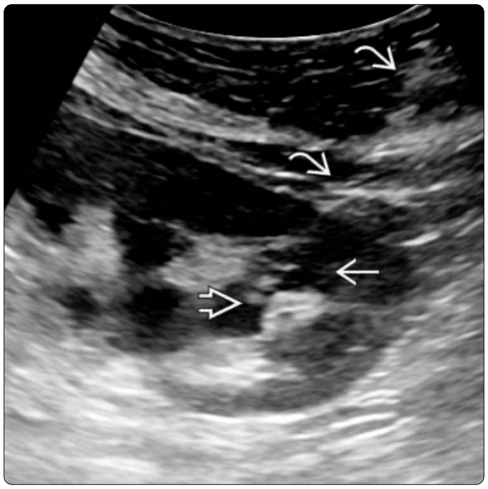


(Left) *After the skin overlying the kidney is sterilely prepared and draped to isolate a sterile field, 1% lidocaine ↪ is administered as a local anesthetic. Using a US probe ⇒ that has been wrapped within a sterile probe cover, sonography of the kidney is performed in the sagittal plane.* **(Right)** *A 22-gauge Chiba needle ↪ is advanced into a lower pole posterior calyx ➡ using real-time US guidance. The tip ⇨ of the needle is well visualized within the dilated, echolucent collecting system.*

Percutaneous Nephrostomy: Preparation of Access Site

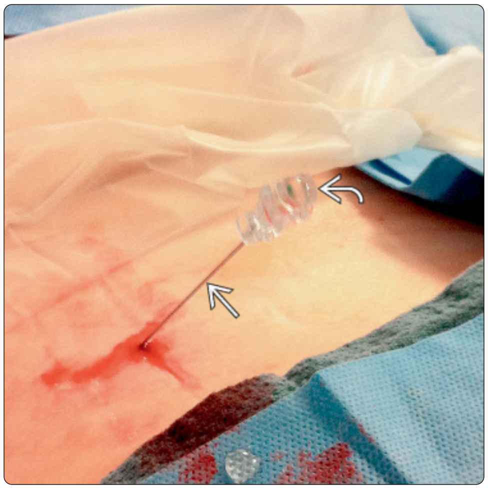


Percutaneous Nephrostomy: US-Guided Needle Placement

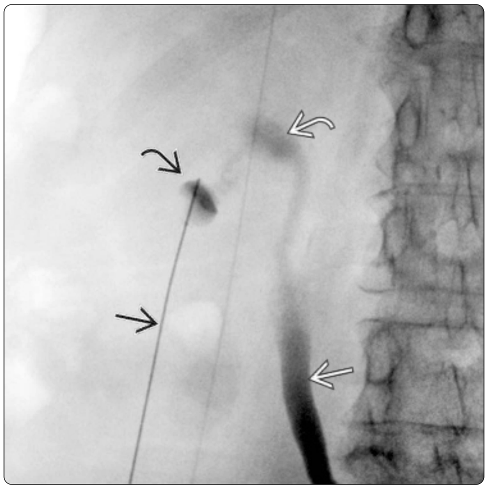


(Left) *After advancing the Chiba needle ➡ into the calyx, the inner stylet is removed. Efflux of urine ↪ confirms position within the collecting system.* **(Right)** *Antegrade nephrogram is performed by injecting contrast through the Chiba needle →. Position in a lower pole calyx ⤷ is confirmed. Contrast opacifies the renal pelvis ↪ and the proximal ureter ➡ as well. Either a 1-stick technique may be used, or, alternatively, a ring needle may be advanced into a different calyx under fluoroscopic guidance (2-stick technique).*

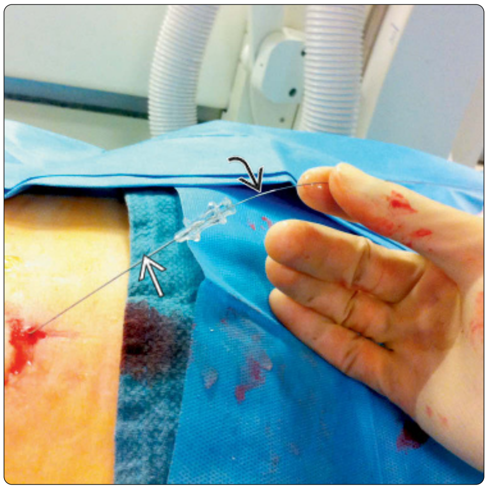
Percutaneous Nephrostomy: US-Guided Needle Placement



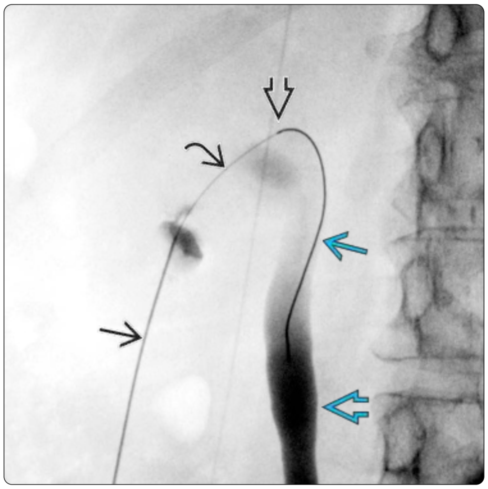
Percutaneous Nephrostomy: Antegrade Nephrostogram



Percutaneous Nephrostomy: 1-Stick Technique

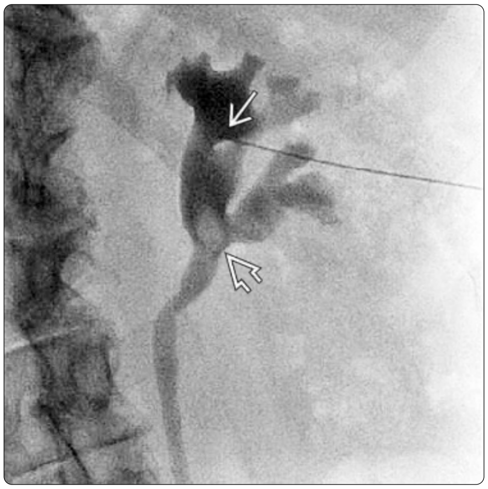


Percutaneous Nephrostomy: 1-Stick Technique

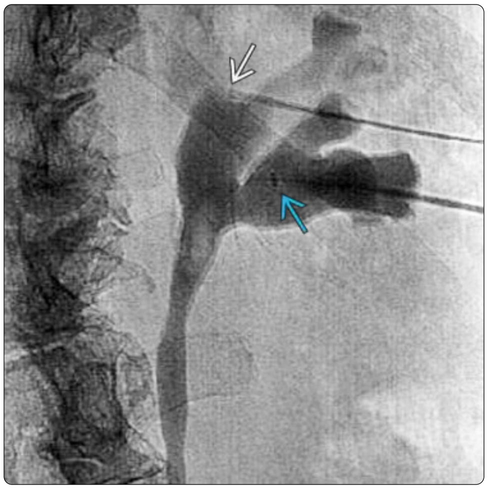


(Left) *Intraoperative photograph shows the 1-stick technique in which a 0.018" guidewire* ↪ *is advanced into the renal collecting system via the 22-gauge Chiba needle* ➡ *used to gain initial access.* **(Right)** *The 0.018" guidewire is advanced through the needle* → *into the proximal ureter* ⇨ *until the stiff portion* ↪ *is in the collecting system. If only the floppy portion* → *is within the system, kinking of the wire during catheter exchanges may occur. The transition* ⇨ *from the stiff to the floppy portion is readily identified fluoroscopically.*

Percutaneous Nephrostomy: 2-Stick Technique

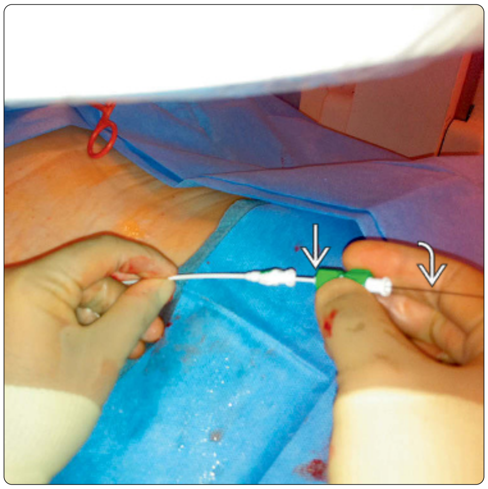


Percutaneous Nephrostomy: 2-Stick Technique

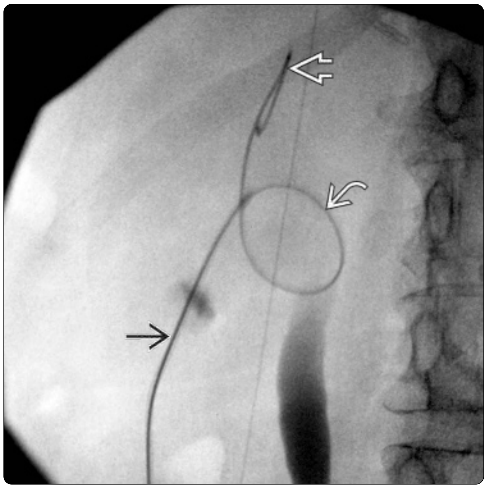


(Left) *Alternate to 1-stick technique, a nephrogram via 22-gauge Chiba needle placed under US guidance shows suboptimal superior calyceal needle access* ➡ *for planned lithotripsy in this patient with a ureteropelvic junction stone* ⇨. **(Right)** *Fluoroscopic triangulation is used to target a more desirable, contrast-filled inferior calyx with a 2nd access needle* →. *During secondary access, repeated contrast filling and dilation of the renal collecting system is performed via the initial access as required* ➡.

Percutaneous Nephrostomy: Coaxial Dilator-Sheath



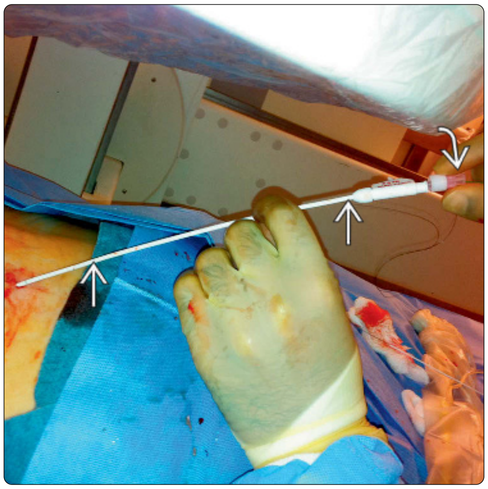
Percutaneous Nephrostomy: Guidewire Placement in Renal Pelvis



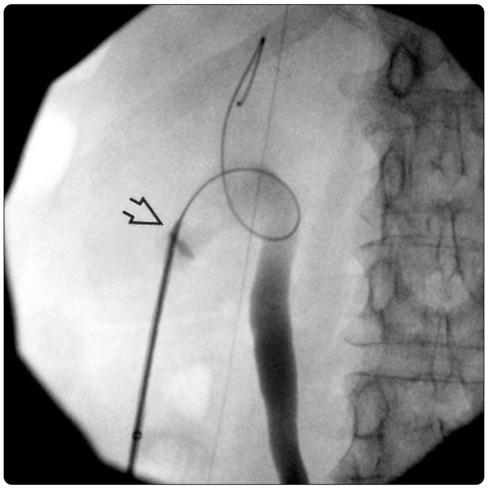
(Left) *The needle has been exchanged for a coaxial dilator-sheath, which was advanced over the guidewire into the renal collecting system. The inner dilator/cannula* ➡ *and 0.018" wire* ↪ *are now removed, and an 0.035" wire will be advanced into the collecting system.* **(Right)** *The 0.035" 3-J guidewire has been advanced through the 6-Fr sheath* →, *forming a loop within the renal pelvis* ↪. *The guidewire tip* ⇨ *is in an upper pole calyx, although it could have been advanced into the ureter as well.*

(Left) *Following tract dilation, an 8-Fr locking pigtail nephrostomy catheter mounted on a metallic inner stiffener is advanced over the guidewire into the renal collecting system. As the system enters the renal pelvis, the inner stiffener ↪ is unscrewed and held in position while the softer catheter ➡ tracks over the wire into the collecting system.* **(Right)** *Fluoroscopic imaging shows the nephrostomy catheter tip entering the collecting system ⇨. At this point, advancing the inner stiffener further risks injury to the kidney.*

Percutaneous Nephrostomy: Catheter Placement

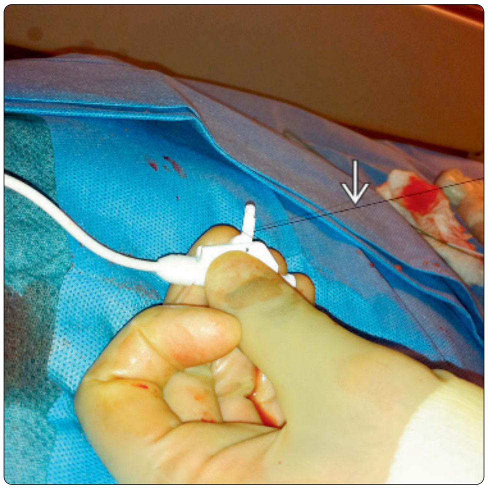


Percutaneous Nephrostomy: Catheter Placement

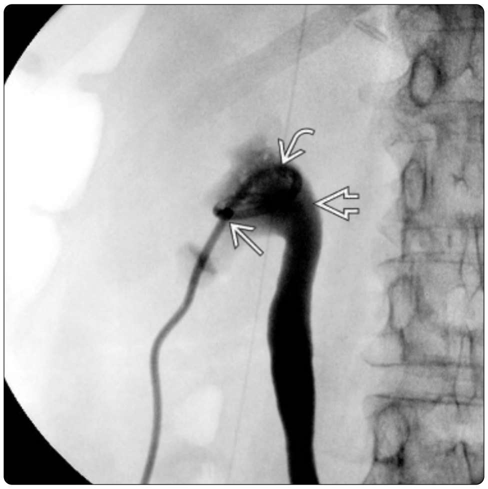


(Left) *After the nephrostomy catheter has been satisfactorily positioned within the collecting system, the guidewire is removed, and the string ➡ is pulled to form the distal pigtail of the catheter.* **(Right)** *Injection of contrast via the nephrostomy catheter confirms appropriate position. Ensure that both the pigtail ↪ and the radiopaque marker ➡ lie within the renal pelvis ⇨.*

Percutaneous Nephrostomy: Catheter Placement

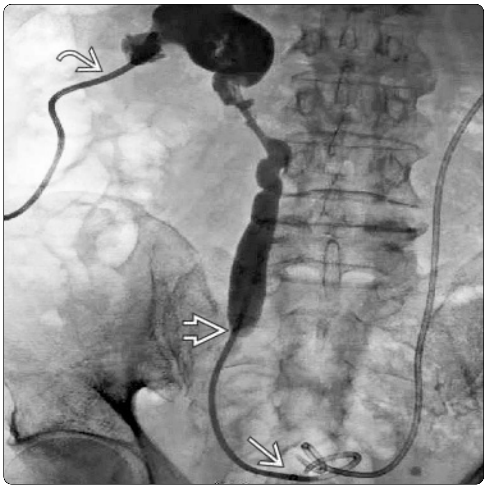


Percutaneous Nephrostomy: Catheter Placement

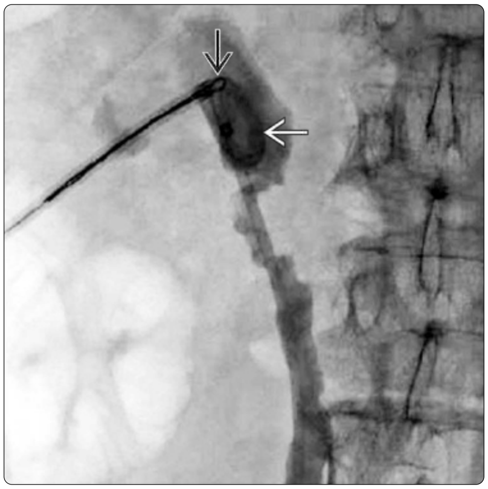


(Left) *A man with left PCN and double-J ureteral stent complained of leakage from the skin entry site. An antegrade nephrostogram shows patent PCN ↪, obstruction of the double J ureteral stent, and no contrast passing into the bladder ➡. Stenosis of the midleft ureter ⇨ is highlighted.* **(Right)** *Ureteral stent removal was requested. After removal of the PCN over a wire, a snare → was inserted through a sheath. The clogged double J ureteral stent ➡ was captured and removed through the sheath.*

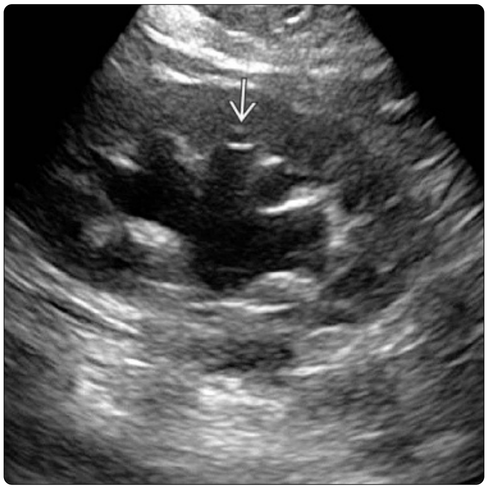
Ureteral Stent Removal: Antegrade Nephrostogram



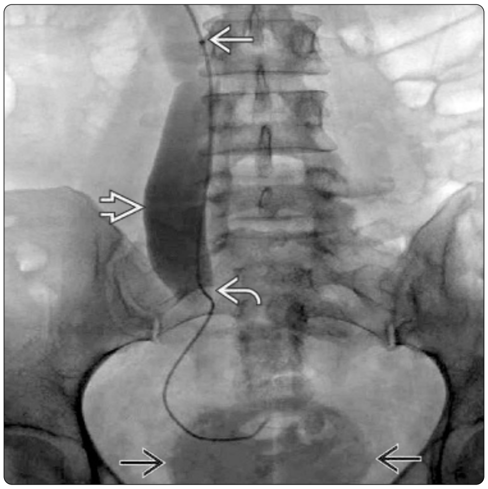
Ureteral Stent Removal: Snaring Ureteral Stent



Percutaneous Nephroureteral Drain: US Access

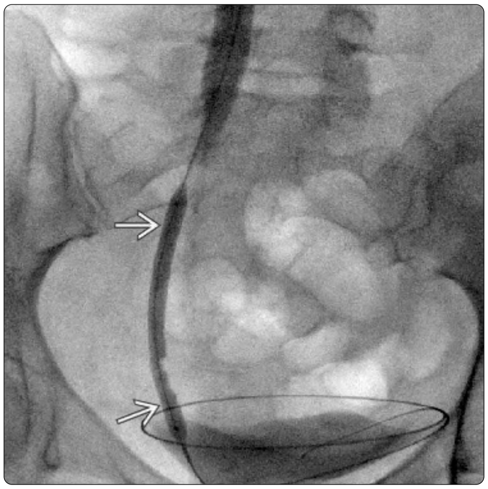


Percutaneous Nephroureteral Drain: Antegrade Nephrostogram

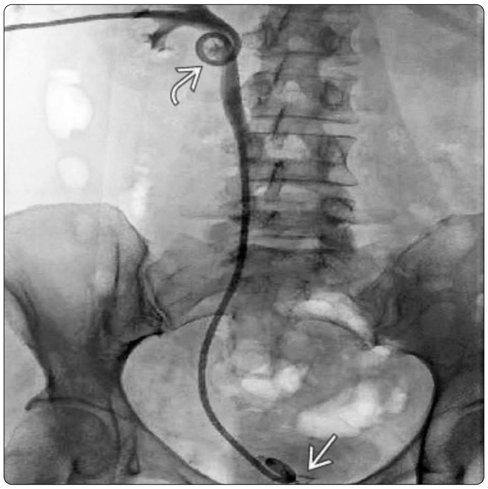


(Left) *A 39-year-old woman with metastatic cervical cancer presented for PCNU placement after a CT demonstrated hydroureteronephrosis. A dilated midpole calyx ➡ was targeted during percutaneous US-guided access.* **(Right)** *Antegrade ureterogram via 6-Fr sheath ➡ in the midureter shows massive hydroureter ⇨ due to distal obstruction ↩. A hydrophilic wire and 4-Fr catheter ⇒ traversed the obstruction, and contrast injected through the catheter confirmed intraluminal position within the bladder.*

Percutaneous Nephroureteral Drain: Balloon Ureteroplasty

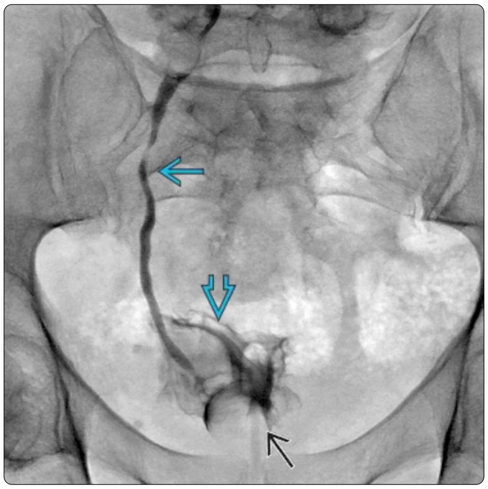


Percutaneous Nephroureteral Drain: Antegrade Nephrostogram

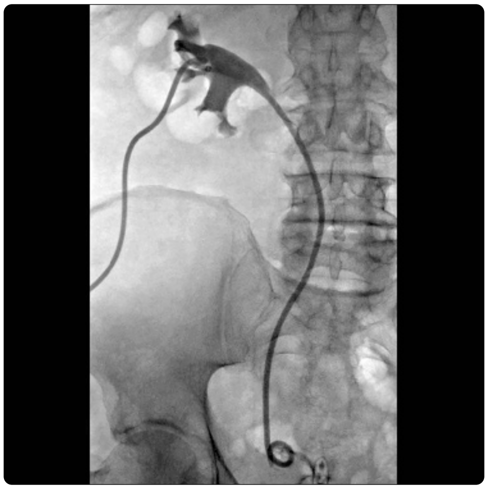


(Left) *Ureteroplasty was performed at the stenosis utilizing a 6-mm diameter balloon ➡. Unfortunately, the ureteral stricture was due to extrinsic compression by metastatic cervical cancer. The ureter did not remain patent upon removal of the balloon.* **(Right)** *Antegrade nephrostogram after over-the-wire PCNU placement shows contrast filling the bladder ➡, successfully crossing the distal ureteral obstruction. Ideally, the proximal pigtail ↩ could be withdrawn slightly within the renal pelvis.*

Ureteral Injury: Postoperative Ureteral Leak

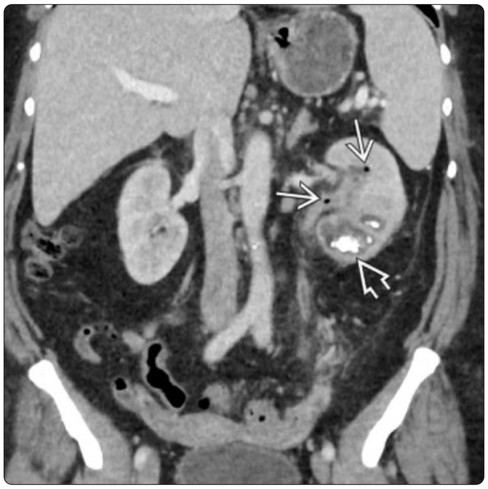


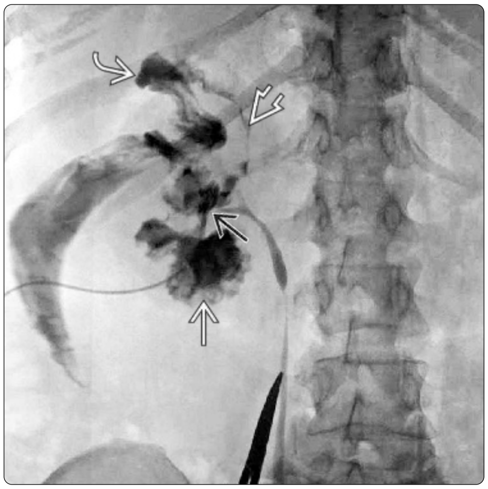
Ureteral Injury: Postoperative Ureteral Leak



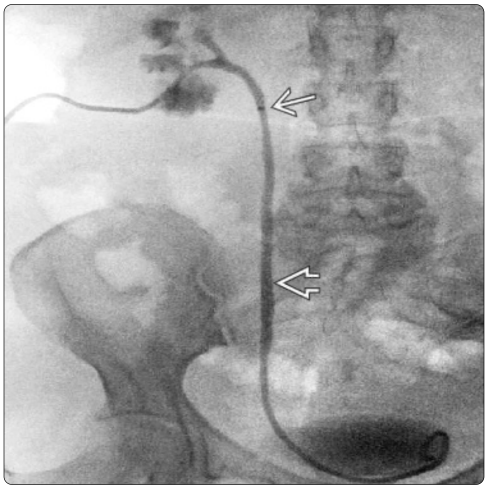
(Left) *Suspected ureteral injury during hysterectomy was confirmed by antegrade ureterogram showing both intra- and extracystic contrast ⇨. Note decompressed ureter ⇒ and Foley catheter outlined within bladder ⇒.* **(Right)** *Ureteral injury was carefully traversed with a nonangled hydrophilic wire and 4-Fr catheter, and a PCNU was deployed. PCNU acts as scaffolding for healing ureter and prevents leakage. After 8 weeks, the ureter was healed, and the patient was spared ureteral reimplantation surgery.*

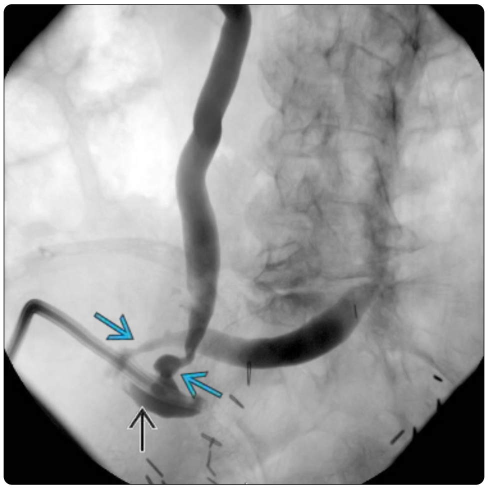
(Left) *A 68-year-old woman presented with left flank pain and recurrent UTI. CECT shows calcifications in the dilated lower pole calyx* ➡*. Foci of air* ➡ *were seen in the kidney and ureter, suspicious for fistula. The patient was referred to an interventional radiologist for PCN placement.* **(Right)** *Antegrade nephrogram after PCN* ⇨ *placement shows dilated inferior pole calyces* ➡ *from chronic obstruction and a fistula* ➡ *to the adjacent descending colon* ↪*. Both fistula and chronic obstruction are indications for PCN placement.*


Colorenal Fistula

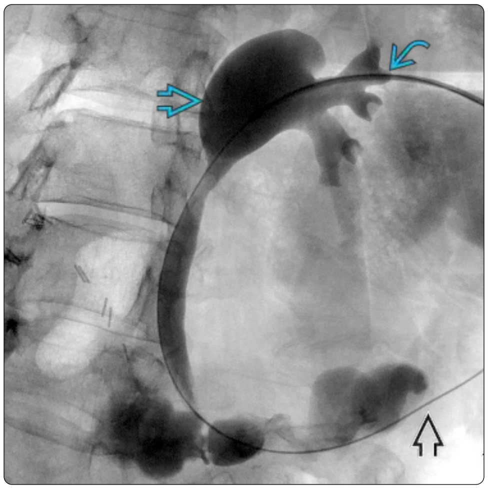

Colorenal Fistula: Antegrade Nephrogram After Percutaneous Nephrostomy

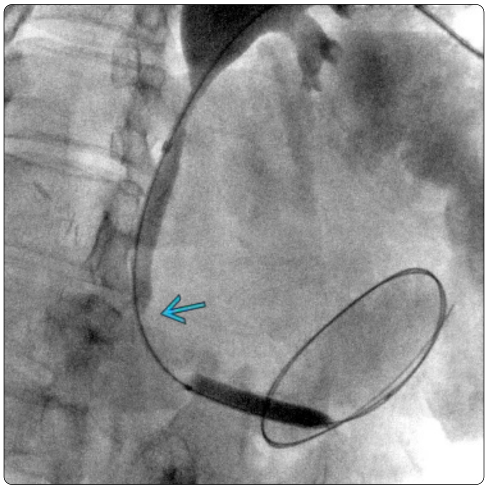
(Left) *Follow-up imaging 1 month later shows resolution of the colorenal fistula. The PCN was converted to a PCNU* ➡*, allowing internal drainage and removal of the external collection bag. The proximal radiodense marker* ➡ *will be withdrawn slightly as the pigtail is formed.* **(Right)** *Retrograde pyelography was performed in a patient status post cystectomy with ileal conduit creation. Contrast injected through a Foley catheter in the conduit* ⇨ *via an ostomy reveals moderate to severe anastomotic narrowing* ⇨*.*


Colorenal Fistula: Exchange for Percutaneous Nephrostomy Nephroureteral

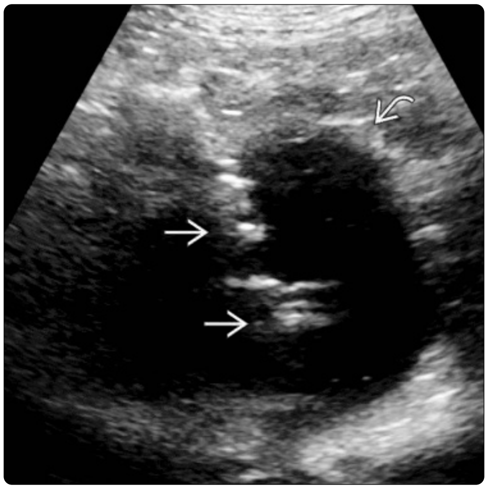

Ileal Conduit: Normal Retrograde

(Left) *Contrast injected via a sheath accessing the superior renal calyx* ⇨ *reveals severe hydronephrosis* ⇨ *and slow passage of contrast into the ileal conduit. A wire crosses the anastomosis into the conduit* ⇨*.* **(Right)** *High-grade narrowing of the ureter at the anastomosis* ⇨ *did not improve following ureteroplasty, necessitating placement of a PCNU (not shown). The ureteroplasty balloon is located within the conduit in this image.*

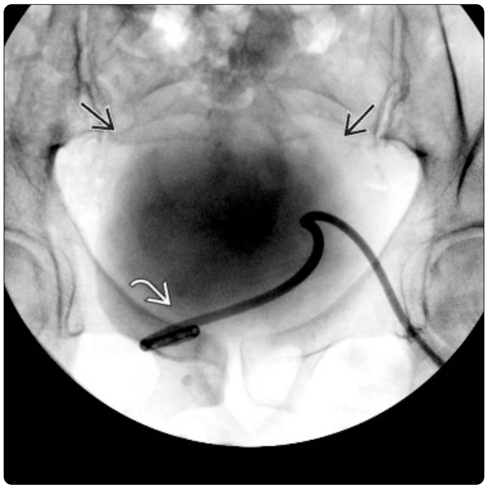

Ileal Conduit Anastomotic Stricture: Antegrade Pyelogram


Ileal Conduit Anastomotic Stricture: Ureteroplasty

Suprapubic Cystostomy: Trocar Technique

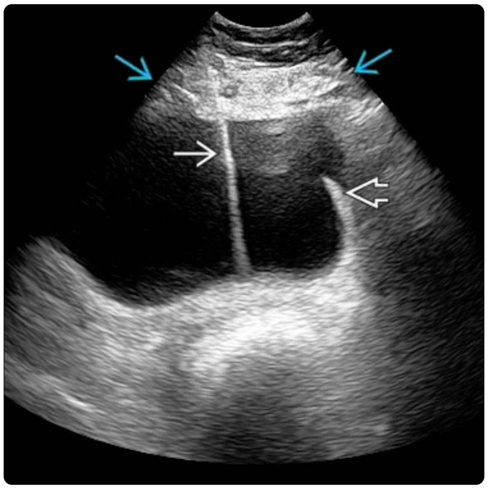


Suprapubic Cystostomy: Trocar Technique

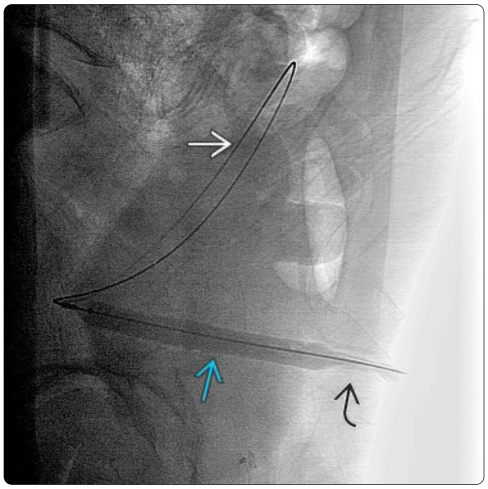


(Left) *The urinary bladder ↪ was distended with saline via transurethral catheter. Then, US was used to guide percutaneous advancement of a trocar mounted with a 14-Fr Foley catheter → into the bladder. A strong thrust is used to puncture, rather than tent, the bladder wall.* **(Right)** *Similarly, a trocar-mounted, 12-Fr locking pigtail cystostomy catheter ↪ can be advanced percutaneously under US guidance. After placement, contrast injected through the catheter confirms appropriate position within the bladder →.*

Suprapubic Cystostomy: Seldinger Technique (Wire Advancement)

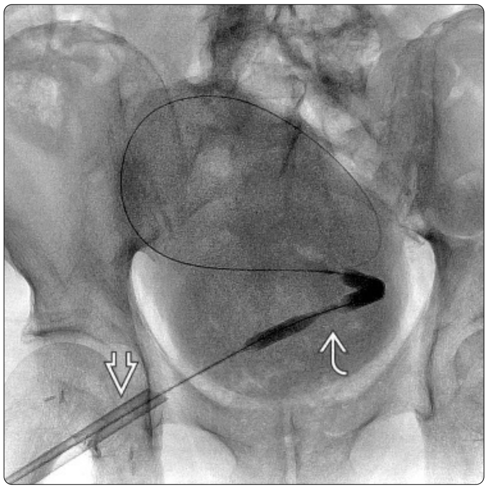


Suprapubic Cystostomy: Seldinger Technique (Balloon Dilation of Tract)

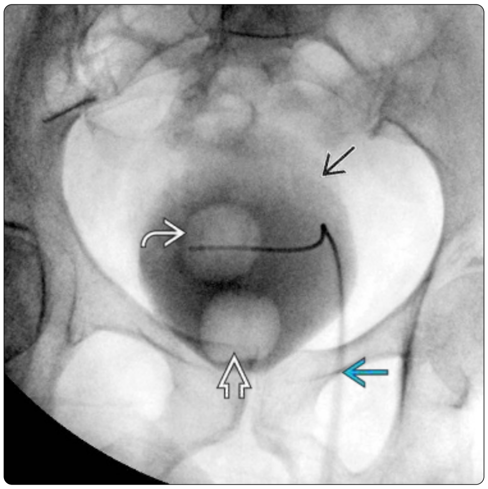


(Left) *After filling the bladder with 250 cc of saline via transurethral catheter, the space anterior to the bladder → is carefully evaluated for signs of bowel or peristalsis. US-guided percutaneous access to the bladder is then achieved with an 18-gauge trocar → through which an 0.035'' wire ⇨ is advanced.* **(Right)** *Lateral imaging is imperative to confirm wire location within the bladder → during tract dilatation with sequential dilators or with a balloon →, as was done in this case. Note wasting due to the bladder wall ↪.*

Suprapubic Cystostomy: Seldinger Technique (Sheath Advancement)



Suprapubic Cystostomy: Seldinger Technique (Final Position)



(Left) *Resolution of balloon wasting ↪ requires exceptionally high balloon pressures. Once the tract is dilated, a sheath ⇨ (rigid over the balloon; peel away following dilators) may be advanced into the bladder through which an SPB catheter will be advanced. Alternatively, the SPB catheter may be advanced directly over the wire.* **(Right)** *Contrast injected through the SPB catheter → confirms the appropriate position within the urinary bladder →. Note suprapubic ↪, transurethral ⇨ catheter balloons.*

KEY FACTS

TERMINOLOGY

- **Hysterosalpingography**: Contrast injection into endometrial cavity with fluoroscopy/imaging
- **Selective salpingography**: Selective contrast injection of fallopian tubal ostium with fluoroscopy/imaging
- **Fallopian tube recanalization**: Guidewire passage through occluded fallopian tubes (FT) to reestablish patency
- **Fallopian tube occlusion**: Placement of mechanical occluding device into FT
- **Sonohysterography**: Injection of sterile saline into endometrial canal during transvaginal ultrasound

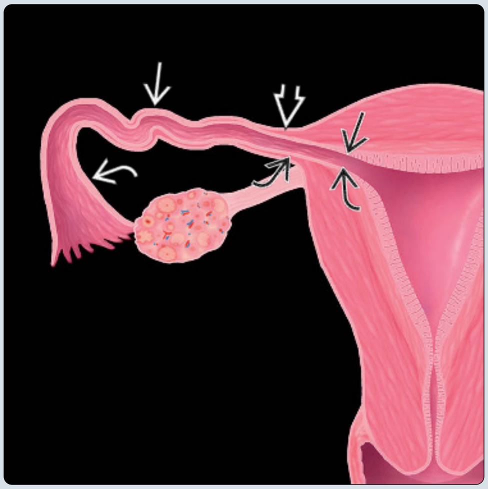
PREPROCEDURE

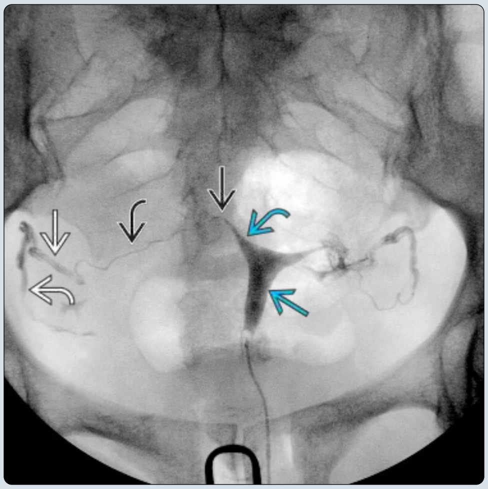
- Selective salpingography indications
  - Differentiate spasm from true obstruction
  - Inadequate fallopian tube opacification by HSG
- FTR indications
  - Tubal occlusion despite selective salpingography
- FTO indications
  - Prophylaxis against unwanted pregnancy
- Sonohysterography indications
  - Dysfunctional uterine bleeding, infertility, miscarriages

PROCEDURE

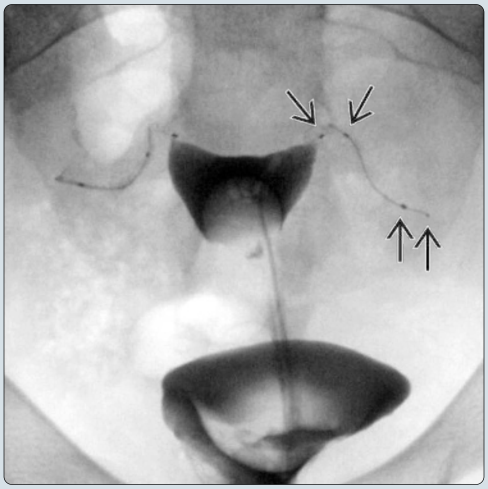
- **Selective salpingography**
  - Advance 4- to 5-Fr catheter over 0.035" guidewire; wedge tip in uterine cornual region
  - Gently inject contrast medium; obtain images
- **FTR**
  - Advance catheter/guidewire through obstruction
- **FTO**
  - Place device in most challenging side 1st
  - Engage 5-Fr working port in tubal ostium
  - Advance device until 3rd radiopaque marker at tubal ostium; deploy Essure coil
- **Sonohysterography**
  - Advance a 5- to 7-Fr catheter through cervix; infuse sterile saline while imaging with transvaginal probe

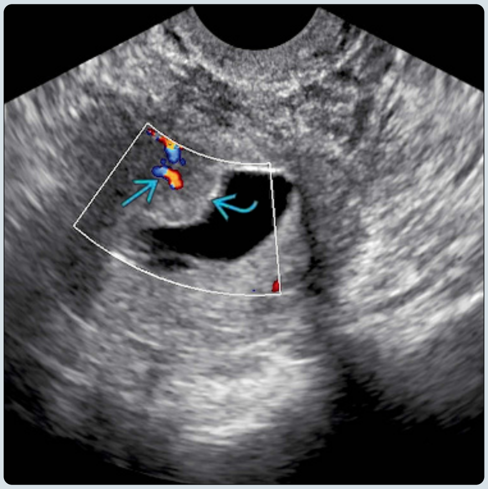
(Left) *Graphic shows a normal fallopian tube. From the ostium →, the interstitial segment → transitions to the isthmic segment at the uterotubal junction →. The remaining segments are termed ampullary → and infundibular →.* **(Right)** *Hysterosalpingogram (HSG) shows a normal endometrial cavity →, the tubal ostium →, uterotubal junction →, and fallopian tubes (isthmic →, ampullary →, and infundibular → segments). Both fallopian tubes are widely patent.*


Normal Fallopian Tube


Normal Hysterosalpingogram

(Left) *Partial-fill view of the uterine cavity from a HSG obtained 3 months after bilateral Essure placement shows that both devices are in satisfactory position. Each device has a series of 4 radiopaque markers → that aid in determining proper positioning during the procedure and on follow-up imaging.* **(Right)** *Endometrial polyps → can be distinguished from blood clots by the vascular pedicle (in this case a single feeding artery → entering the endometrial polyp) and lack of mobility.*


Fallopian Tube Occlusion (Successful Tubal Occlusion)


Endometrial Polyp (Sonohysterography)

TERMINOLOGY

Definitions

- **Hysterosalpingography (HSG)**: Contrast injection via cervical canal into endometrial cavity with fluoroscopic monitoring/imaging
  - Normally shows filling of uterine cavity and bilateral fallopian tubes (FT)
    - Tubal patency confirmed if contrast spills from tubes into abdominal cavity
  - Sensitivity and specificity in detecting pathology
    - Tubal occlusion defined as bilateral lack of patency: 92% and 87%
    - Tubal occlusion defined as any abnormality (unilateral or bilateral): 78% and 53%
- **Selective salpingography**: Direct selective catheterization of fallopian tubal ostium
  - Contrast injection via catheter during imaging
    - Provides direct opacification of fallopian tube
- **Fallopian tubal anatomy**
  - 4 tubal segments
    - Interstitial (intramural)
    - Isthmic
    - Ampullary
    - Infundibular
  - Uterotubal junction located at transition of intramural to isthmic segment of fallopian tube
    - Narrowest portion of fallopian tube
  - Average tubal diameter: 0.8-2.0 mm
    - Increases as fallopian tube courses toward ovaries
  - Average tubal length: 11 cm (range: 7-16 cm)
- **Fallopian tube recanalization (FTR)**: Guidewire &/or catheter passage through occluded fallopian tube to reestablish tubal patency
  - Fallopian tube disease accounts for up to 35% of infertility cases; various causes
    - Infection (Chlamydia)
    - Postsurgical
    - Salpingitis isthmica nodosa
      - ☐ Inflammation of isthmic or intramural segments; characterized by nodular thickening causing obstruction
      - ☐ Selective fallopian tube catheterization has higher sensitivity due to ability to fill isthmic diverticula beyond proximally occluded tube
    - Peritubal adhesions
  - Proximal tubal occlusion often caused by mucus plug/inflammatory debris; also caused by spasm
    - Involves interstitial segment/uterotubal junction
    - Responds fairly well to recanalization
  - Less favorable outcomes with more distal occlusions
    - More often due to scarring/fibrosis
- **Fallopian tube occlusion (FTO)**: Placement of mechanical occluding device into FT
  - Type of bilateral tubal sterilization
    - Hysteroscopic transcervical fallopian tube access
    - Placement of Essure device (Conceptus; Mountain View, CA) into FT
      - ☐ Combined outer nitinol/inner stainless steel coil elicits tissue growth; occludes FT
      - ☐ During first 3 months, device not fully effective
      - ☐ Alternate birth control needed during this time
- **Sonohysterography**: Injection of sterile saline into endometrial canal during transvaginal ultrasound
  - Enhances detection of endometrial abnormalities not seen on standard ultrasound
  - Increased pelvic free fluid after procedure can indicate at least 1 fallopian tube is patent

PREPROCEDURE

Indications

- **Selective salpingography**
  - Differentiate spasm from true tubal obstruction
  - Inadequate fallopian tube opacification by HSG
- **FTR**
  - Persistent tubal occlusion after selective salpingography
- **FTO**
  - Means of permanent birth control
- **Sonohysterography**
  - Evaluate causes of dysfunctional uterine bleeding, infertility, and recurrent pregnancy loss
    - Usually submucosal fibroids, endometrial polyps/hyperplasia/malignancy, congenital anomalies, and intrauterine adhesions

Contraindications

- **Selective salpingography**
  - Active infection
- **FTR**
  - Active infection
- **FTO**
  - Desire to maintain fertility
  - Pregnancy; recent or current infection
  - Essure device-related contraindications
    - Prior tubal ligation
    - Pregnancy termination/child delivery < 6 weeks before intended placement
    - Immunosuppression
    - Menorrhagia/metrorrhagia of unknown etiology
    - Allergy to nickel or other insert components (titanium, silver, platinum, tin)
- **Sonohysterography**
  - Active infection
  - Pregnancy

Getting Started

- Things to check
  - Detailed clinical and physical evaluation
    - Evaluation of symptoms; exclude other diagnosis
    - Gynecological evaluation and pelvic examination
      - ☐ Normal Papanicolaou test
      - ☐ Gonorrhea/*Chlamydia* cultures negative
  - Negative qualitative urinary β-hCG on day of procedure
    - Additional laboratory studies unnecessary
  - Allergies
  - Selective salpingography: Review images/anatomy
  - FTR: Document fallopian tubal occlusion
  - Procedure timing
    - FTO: Perform in follicular phase (day 7-10) of menses; limits chance of luteal phase pregnancy

    - Sonohysterography: Perform after cessation of menstruation but before day 10 of cycle
- Medications
  - Ketorolac (30 mg) IV
    - Addresses postprocedural pain and cramping
    - May decrease tubal spasm
  - Antibiotic prophylaxis (widely practiced, not universal)
    - Clindamycin (600 mg) and gentamicin (80 mg) IV
    - If performing only selective salpingography
      - Doxycycline (100 mg) BID for 5 days; start 2 days prior to procedure
  - Intraprocedural conscious sedation
  - Paracervical block anesthesia
    - 3-5 mL of lidocaine at 4 and 8 o'clock positions
  - May use antiinflammatories or antibiotics along with sonohysterography
- Equipment list
  - Speculum
  - Transcervical access catheter/device for HSG (various options)
    - Thurmond-Rösch Hysterocath (Cook Medical; Bloomington, IN)
      - Can be used to introduce catheters/other instruments up to 9 Fr
    - 9-Fr sheath in endometrial cavity
    - 12-Fr transcervical catheter with balloon
  - Essure device
    - 4.3-Fr outer diameter delivery system
    - Placed via 5-Fr catheter working port
  - Catheters for selective FT catheterization
    - 4-Fr angled-tip catheter
    - 5-Fr Kumpe catheter
  - Catheter for FT recanalization
    - Thurmond-Rösch fallopian tube catheterization set (Cook Medical; Bloomington, IN)
      - 3-Fr tapered coaxial catheter preloaded over 0.015" guidewire
  - Sonohysterography: 5- to 7-Fr catheter, transvaginal ultrasound probe, warm sterile saline, 20-mL syringe

PROCEDURE

Patient Position/Location

- Patient in lithotomy position

Equipment Preparation

- Fluoroscopic studies: Dilute contrast medium to 30%
  - Allows visualization of catheters/guidewires

Procedure Steps

- **Cervical cannulation for HSG/FTR/FTO**
  - Sterilely prepare/drape vulvar and perineal area
  - Introduce speculum; visualize cervix
  - Place 9- to 12-Fr occlusive catheter and fix it with tenaculum, external cervical suction, or endocervical/uterine balloon
  - Place 5-Fr diagnostic catheter
    - Inject contrast to opacify uterine cavity
- **Selective salpingography**
  - Advance 4- to 5-Fr catheter over 0.035" guidewire; wedge catheter tip in cornual region
    - Thurmond-Rösch set used by most physicians
  - Gently inject contrast medium
  - Perform contralateral fallopian tube catheterization
- **FTR**
  - 3-Fr tapered catheter preloaded over 0.014-0.018" guidewire
  - Advance catheter/guidewire through obstruction
  - Persistent obstruction
    - Cross with 0.014-0.018" diameter floppy-tip/0.035" hydrophilic guidewire
    - Use firm traction on cervix to straighten uterus
- **Sonohysterography**: Steps differ from fluoroscopic procedures (above) after sterile prep and cervical visualization
  - Precatheterization images should be obtained and recorded, in at least 2 planes
    - Include thickest bilayer endometrial measurement obtained in sagittal view
  - Flushed 5- to 7-Fr balloon-tip catheter is inserted into cervical canal
  - Inflate catheter balloon tip with saline
  - Remove speculum and insert transvaginal probe alongside catheter
  - Instill warm sterile saline into endometrial cavity with 20-mL syringe attached to catheter, actual amount varies (~ 40 cc)
  - Real-time scanning of endometrial and cervical canal

Findings and Reporting

- **Selective salpingography**
  - Selective tubal catheterization: Technically successful in up to 90% of cases
    - 90% of cases with proximal tubal obstruction
    - 80% of cases bilaterally or involving single tube
  - Opacification of normal tube in 20-30% of cases with peritoneal passage of contrast
- **FTR**
  - Improved tubal diagnosis in 90% of cases
  - Restoration of tubal patency in 40% of cases
- **FTO**
  - HSG criteria for grading coil placement and tubal occlusion (3-month follow-up after FTO)
    - Grade I
      - Expulsion of coil or > 50% of coil inner length trails into uterine cavity
      - Tubal occlusion at cornua
    - Grade II
      - < 50% of inner coil length trails into uterine cavity or proximal end of inner coil is < 30 mm into tube from tubal ostium
      - Contrast in tube, not past any portion of coil
    - Grade III
      - Coil inner length proximal end > 30 mm distal to tubal ostium or coil within peritoneal cavity
      - Contrast tracks past coil or into peritoneal cavity
    - Coil placement must be grade II, and tubal occlusion must be grade I or II for sterility
- **Sonohysterography**
  - Distinguish focal (< 25% of endometrial surface) from diffuse endometrial pathologic conditions

  - Color Doppler helpful in evaluating vascularity of intrauterine abnormality.

Alternative Procedures/Therapies

- Surgical
  - Restoration of fallopian tube patency
    - Surgical repair of proximal tubal occlusion
    - Falloscopic tuboplasty
  - Bilateral tubal sterilization
    - Tubal ligation rather than FTO
- Other
  - Hysteroscopic placement of Essure device
  - Hysterosalpingo-contrast-sonography is alternative to HSG or sonohysterography

POST PROCEDURE

Things to Do

- FTO
  - **Instruct patient to use alternative form of contraception for 3 months after procedure**
  - **Perform follow-up HSG in 3 months to confirm successful tubal occlusion**
    - HSG alternate: Conceptus protocol (6-radiograph minimum)
      - Scout, minimal/partial/total fill uterine cavity views, bilateral oblique magnification uterine cornua views
  - Reassure that vaginal spotting and cramping expected (may treat cramping with NSAIDS)
- FTR
  - Repeat HSG in patients who fail to achieve pregnancy

OUTCOMES

Complications

- Immediate/periprocedural complication(s)
  - Tubal perforation: 2% of cases
    - Often actually submucosal guidewire passage
  - Contrast intravasation
    - Can occur if catheter poorly positioned
  - Infection (extremely rare)
    - Peritonitis: Incidence < 1%
    - Pyosalpinx, endometritis
  - Improper Essure placement (too proximal)
    - Immediate hysteroscopic insert removal should not be attempted unless 18 or more coils of Essure insert are trailing into uterine cavity
      - Attempted removal with < 18 trailing coils may result in fractured insert, fallopian tube perforation, or other injury
- Delayed complication(s)
  - Extrauterine (ectopic) pregnancy
    - Tubal pregnancies reported in up to 3% of women after FTR
    - Higher risk after FTR but less than after microsurgical tubal intervention
    - Close follow-up with gynecologist
- Other complications
  - Radiation exposure
    - Ovarian exposure ~ 1 rad (10 mGy)
    - Perform procedures in follicular phase of ovulatory cycle to ensure patient not pregnant
  - Sonohysterography: Typically limited to nausea or fever (< 1%), and pelvic pain (4%)

Expected Outcomes

- FTR
  - Procedural success: 71-92%
  - Pregnancy rates: Variable; up to 30%
    - If pregnancy occurs, typically within 6 months of FTR
- FTO
  - Efficacy rate of Essure preventing pregnancy: 99.8%
  - Pregnancy occurrence following Essure placement most commonly due to noncompliance with postplacement procedure protocol
    - Failure to undergo 3-month follow-up HSG
    - Failure to prescribe/take contraception in interim
  - Vaginal spotting, pelvic cramping expected afterward
  - Hysteroscopic sterilization is associated with lower pregnancy rates and lower complication rates compared to laparoscopic tubal ligation

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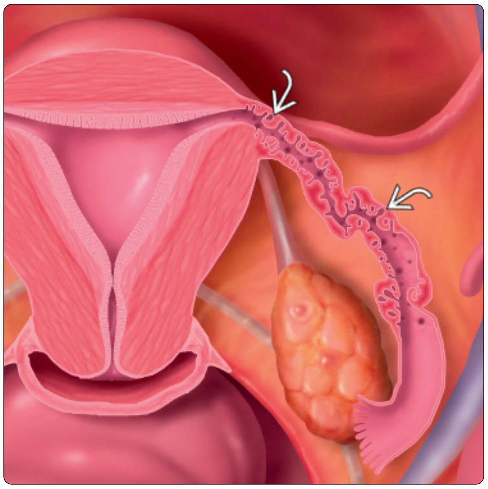
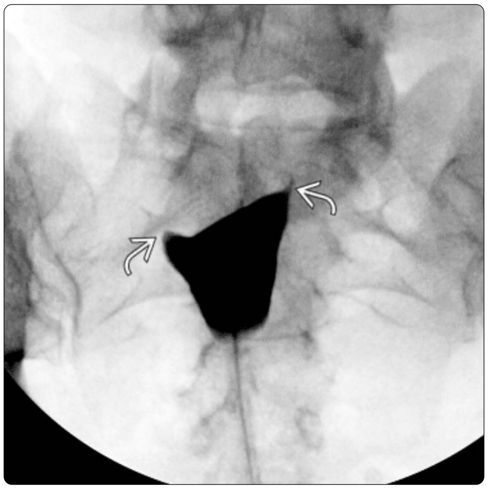
(Left) *Fallopian tube disease accounts for up to 35% of infertility cases with various causes for tubal occlusion. This graphic shows a diseased left fallopian tube* ➡ *due to salpingitis. Alternatively, the proximal tube may be occluded by inflammatory debris and may be amenable to recanalization.* **(Right)** *Initial evaluation is via HSG. After accessing the cervix and endometrial canal, contrast medium is injected, and images are obtained. In this case, there is bilateral fallopian tube occlusion at the ostia* ➡*.*

Fallopian Tube Recanalization (Tubal Occlusion From Salpingitis)

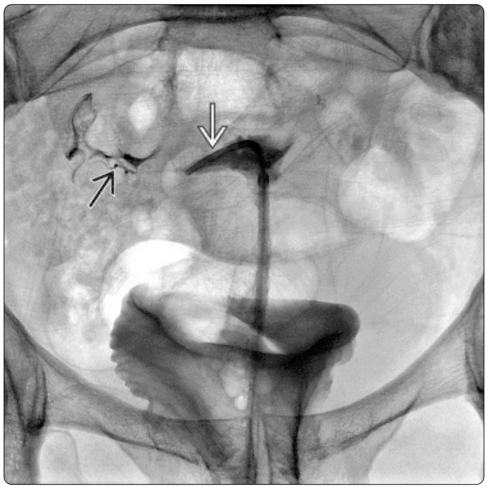


Fallopian Tube Recanalization (Initial Hysterosalpingogram)

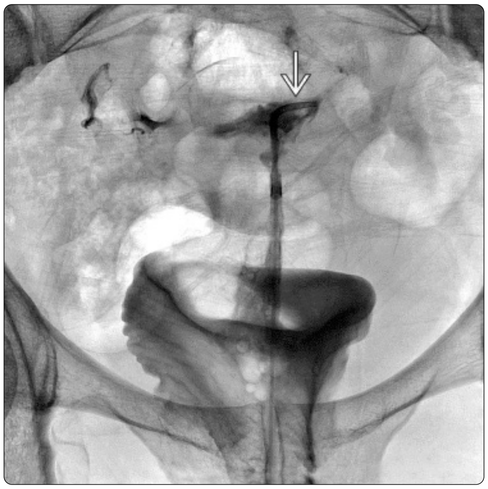


(Left) *The tip of an angled catheter* ➡ *has been placed at the right tubal ostium for selective salpingography, showing a patent fallopian tube* ⇨*. It is not uncommon that proximal occlusion, as seen on a prior HSG, is no longer present (reported in up to 40% of patients). Although contrast injection may dislodge occluding debris, guidewire passage is more often required.* **(Right)** *The angled catheter* ➡ *was redirected to the left cornu, where contrast injection fails to fill the fallopian tube, indicating tubal occlusion.*

Fallopian Tube Recanalization (Selective Right Salpingography)

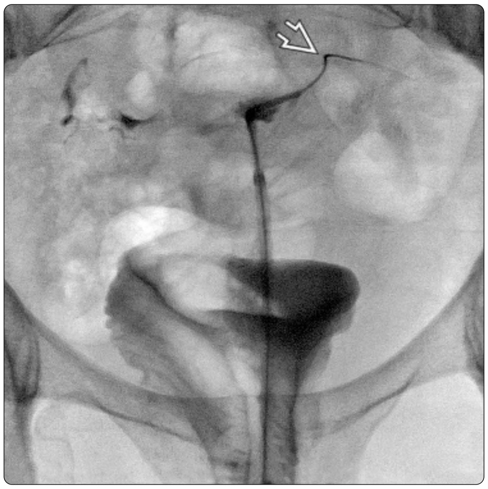


Fallopian Tube Recanalization (Selective Left Salpingography)

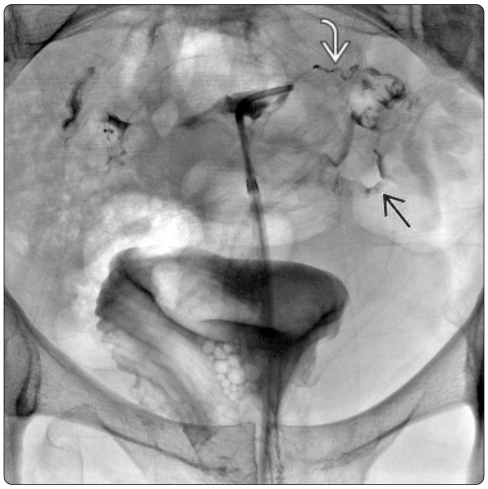


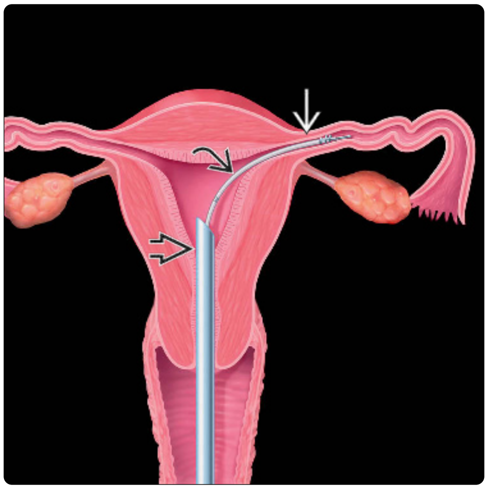
(Left) *After cannulating the fallopian tube orifice, a 0.018" guidewire* ➡ *has been advanced into the interstitial tubal segment in an attempt to dislodge any occluding debris.* **(Right)** *Left salpingogram after guidewire passage shows the fallopian tube* ➡ *is patent with free contrast spillage* ⇨ *into the peritoneal cavity. There is a high technical success rate for recanalization, but conception rates are unfortunately much lower and are generally reported at around 30%.*

Fallopian Tube Recanalization (Guidewire Passage on Left)

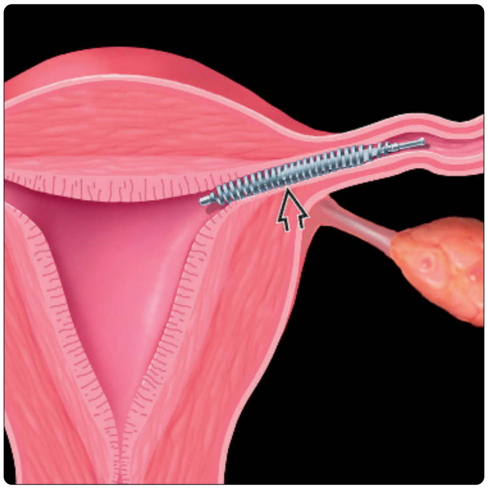


Fallopian Tube Recanalization (Final Hysterosalpingography)



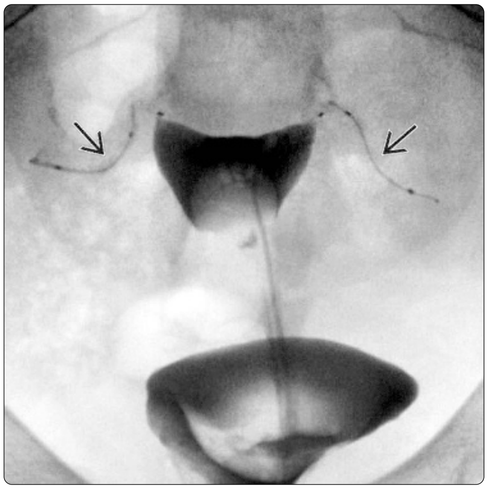


Fallopian Tube Occlusion (Cannulation of Tubal Ostium)

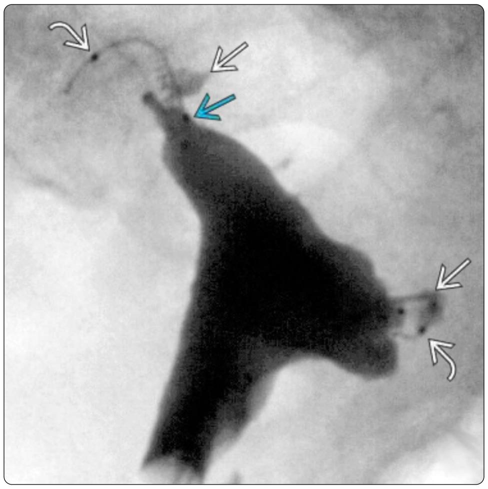


Fallopian Tube Occlusion (Essure Device Placement)

(Left) *Graphic shows a transcervical cannula* → *in place, through which the 4.3-Fr diameter delivery system* → *for the Essure device has been introduced. The left fallopian tube ostium has been selectively cannulated, and the device has been advanced so that it will span the uterotubal junction* → *once it is deployed.* **(Right)** *Graphic shows the deployed Essure device* → *in place. The combined outer nitinol and inner stainless steel coils elicit tissue ingrowth, which will occlude the fallopian tubes over a period of 3 months.*

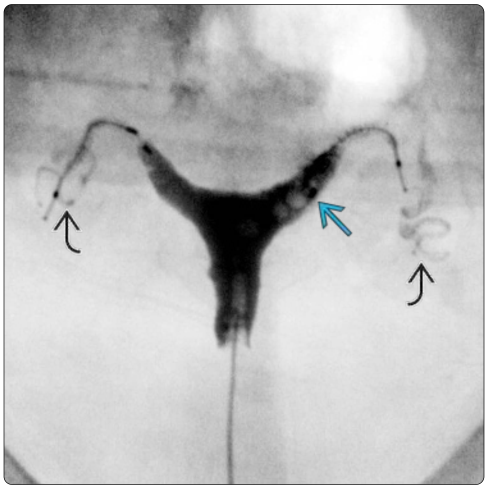


Fallopian Tube Occlusion (Successful Tubal Occlusion)

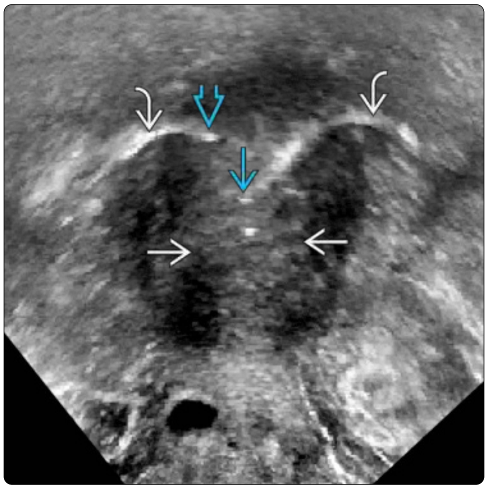


Fallopian Tube Occlusion (Incomplete Tubal Occlusion)

(Left) *HSG obtained 3 months after bilateral Essure* → *placement shows both devices are in satisfactory position. Contrast fails to fill the fallopian tubes, consistent with successful tubal occlusion.* **(Right)** *HSG 3 months after bilateral Essure placement shows both devices* → *well positioned (3rd marker at tubal ostium* →*), but contrast* → *tracks proximally into the tubes. This indicates incomplete tubal occlusion; contrast should not extend beyond any portion of the coil.*



Fallopian Tube Occlusion (Malpositioned Essure Device, Incomplete Occlusion)



Fallopian Tube Occlusion (Malpositioned Essure Device)

(Left) *In this case, the left Essure device tip* → *extends too far into the uterine cavity, while the right device is optimally positioned. In addition, contrast fills both fallopian tubes* →*, indicating tubal patency despite the procedure 3 months earlier.* **(Right)** *Transvaginal uterine ultrasound in the same patient shows the endometrial cavity* → *and bilateral Essure devices* →*. The tip* → *of the right device extends slightly into the cornu. The left device is malpositioned with the tip* → *extending into the uterine cavity.*

Thoracic Drainage

KEY FACTS

PREPROCEDURE

- **Indications**
  - Diagnostic thoracentesis: Effusion of unknown etiology
  - Therapeutic thoracentesis: Symptomatic effusion
  - Chest tube placement: Pneumothorax, empyema, pleural effusion, hemothorax
  - Tunneled pleural catheter: Symptomatic recurrent/refractory pleural effusion
  - Percutaneous drain in lung: Abscess

PROCEDURE

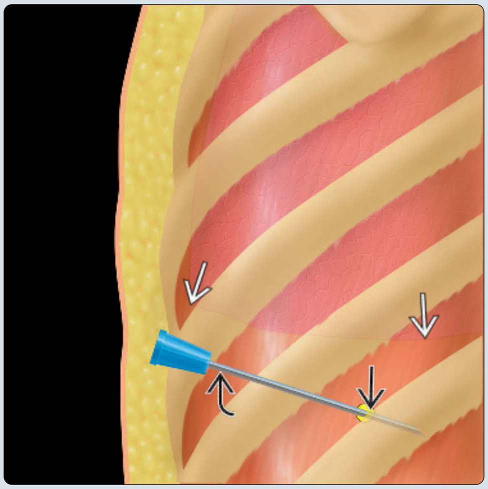
- **General**
  - Introduce catheter/needle over superior aspect of rib
  - Direct trocar vs. tandem trocar vs. Seldinger techniques
- **Thoracentesis**
  - For dependent pleural effusion, patient sitting upright, arms folded over table
  - Posterior or posterolateral approach
- **Pneumothorax**
  - Patient supine, anterior or anterolateral approach
  - Attach chest tube to water-seal system ± (-20 mm Hg)
- **Tunneled pleural catheter**
  - Patient supine, placement at anterolateral chest
  - Leakage indicative of incomplete aspiration of effusion
  - Arrange nursing/home health follow-up to instruct proper usage of catheter
- **Lung abscess**
  - Shortest route that minimizes traversal of lung parenchyma

POST PROCEDURE

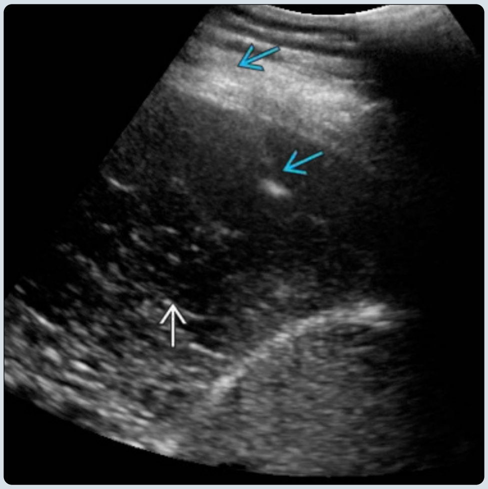
- Obtain chest radiograph, postprocedure & daily
- Chest tube removal (pneumothorax)
  - Place on water seal, when no pneumothorax/air leak x 24 hr, clamp tube x 4 hr, repeat CXR
  - If no pneumothorax on repeat CXR, remove tube
- Disruption of pleural septations
  - Infuse 5 mg tPA + 5 mg DNase, 2x daily for 3 days

(Left) *Graphic shows fluid* ➡ *in the chest representing a pleural effusion. A small catheter* ⤻ *has been introduced over the superior aspect of the rib* ⇨*, thus avoiding the neurovascular structures that course below each rib.* **(Right)** *Therapeutic thoracentesis was requested and the patient was brought to ultrasonography. US reveals the pleural fluid to be heteroechoic with innumerable septations* ➡*; empyema was suspected. An 18-g trocar* ⇨ *was percutaneously advanced into the fluid.*

Intercostal Access Graphic

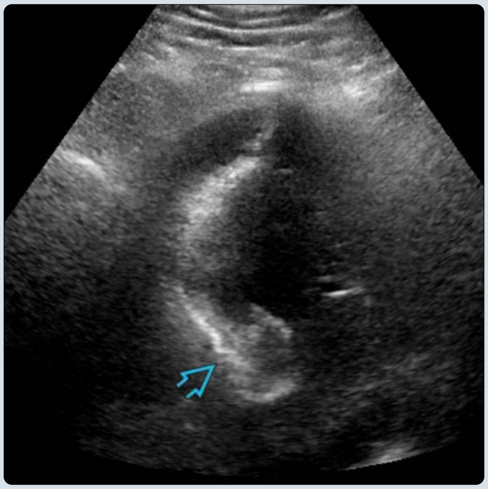


Empyema (US-Guided Needle Access)

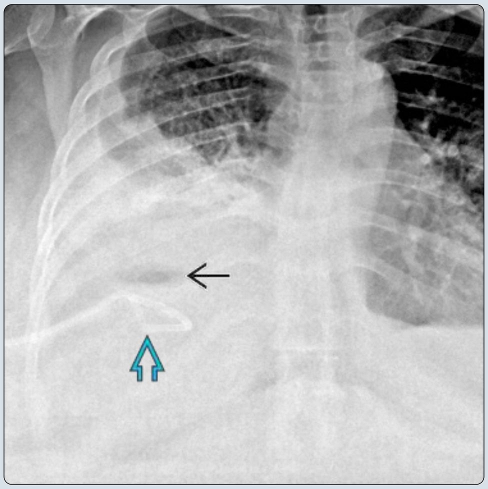


(Left) *Chest tube placement was performed using Seldinger technique, advancing a 10-Fr pigtail drain* ⇨ *over an 0.035" Rosen wire into the collection under US visualization.* **(Right)** *A subsequent chest radiograph shows the drain* ⇨ *centrally positioned within the collection. Air within the collection* ➡ *is related to drain placement. Thick, cloudy, yellow fluid was aspirated and sent for microbiologic review.*

Empyema (US-Guided Pigtail Drain Placement)



Empyema (Post Drain Placement)



PREPROCEDURE

Indications

- **Diagnostic thoracentesis**
  - Pleural effusion of unknown etiology
- **Therapeutic thoracentesis**
  - Symptomatic pleural effusion (e.g., malignant)
- **Chest tube placement**
  - Pneumothorax
  - Empyema
  - Postoperative pleural effusion
  - Hemothorax
- **Tunneled pleural catheter**
  - Symptomatic recurrent/refractory pleural effusion
- **Lung abscess**
  - Usually due to aspiration/pneumonia/septic emboli
  - Typically responds to antibiotics/bronchial lavage
  - Failed response to medical management
    - Thoracotomy vs. percutaneous drainage
    - Percutaneous drainage has risk of creating bronchopleural fistula

Contraindications

- Uncorrectable bleeding diathesis

Preprocedure Imaging

- Review prior chest radiograph, CT, MR, US
  - Confirm presence of effusion or pneumothorax
    - Assess for loculated collection
    - Assess for any collateral vessels in drainage trajectory if vascular obstruction present
- Determine appropriate imaging guidance for procedure
  - US
    - Ideal in cases of pleural effusion
  - CT
    - May be necessary for small loculated collections or pneumothorax
  - Fluoroscopy
    - May use for very large pleural effusion/pneumothorax

Getting Started

- Things to check
  - Clinical history and physical examination
    - Procedure indications
    - Current medications
      - Any anticoagulant or antiplatelet agents
  - Allergies
  - Laboratory parameters
    - Complete blood count (CBC), platelet > 50,000/μL
    - Coagulation profile
      - International normalized ratio (INR) ≤ 2.3 for thoracentesis, 1.5 for chest tube
      - Normal partial thromboplastin time (PTT)
  - Procedural written informed consent
- Medications
  - 1% lidocaine local anesthetic
  - Procedural sedation rarely required
    - Fentanyl/midazolam used if sedation needed
- Equipment list
  - Imaging guidance equipment
    - US equipment
      - 3- to 5-MHz transducer
      - Used to mark entry site on skin
      - Sterile probe cover/gel if real-time guidance
    - CT equipment
      - Radiopaque grid for localizing point of access
    - Fluoroscopy equipment
      - Used less commonly today
  - Diagnostic thoracentesis equipment
    - 18- to 22-gauge spinal needle
  - Therapeutic thoracentesis equipment
    - 6- to 7-Fr drainage catheter
  - Chest tube placement equipment
    - Trocar technique
      - 8- to 16-Fr trocar-mounted catheter
    - Tandem trocar technique
      - 20-g Chiba or spinal guiding needle
      - 8- to 16-Fr trocar-mounted catheter
    - Seldinger technique
      - 18-g (Longdwell) needle
      - 0.035" guidewire with 3-mm J-tip
      - 8- to 16-Fr dilators as appropriate
      - 8- to 16-Fr catheter
    - Tunneled pleural catheter (PleurX, Denver Biomaterials Inc.)
    - Pleur-evac collection system (Teleflex Medical)

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Introduce catheter over superior aspect of rib
    - Vascular structures along inferior surface
  - Dependent pleural effusion
    - Posterior or posterolateral approach
    - Patient sitting upright on stretcher with arms folded over table
      - If unable to sit upright, place in lateral decubitus position with ipsilateral side up
  - Loculated pleural effusion
    - Positioning will depend on location
  - Pneumothorax
    - Anterior or anterolateral approach while supine
  - Tunneled pleural catheter
    - Patient supine, placement at anterolateral chest
  - Lung abscess
    - Shortest route that minimizes traversal of lung parenchyma
      - Prefer gaining access to abscess component that abuts pleura if possible

Procedure Steps

- **General**
  - Review preprocedure preliminary images to verify
    - Target collection adequately visualized with chosen imaging guidance modality
    - Determine safe route to collection
  - Cleanse skin with preparatory solution
  - Place sterile drapes to isolate sterile field
- **Thoracentesis**

  - US is modality of choice for pleural effusions
    - Not applicable in pneumothorax
    - May be unable to image effusion appropriately due to intervening air
  - Visualize collection, mark skin entry site with pen
  - Large effusion, may target without real-time image guidance
  - Occasionally, real-time US guidance useful
    - Place sterile cover on transducer
      - First apply gel on US probe
      - Apply sterile gel externally over probe cover
    - Introduce needle/catheter while imaging
  - Plan access just superior to rib (avoid neurovascular bundle inferior to rib)
  - Administer 1% lidocaine local anesthetic
    - Anesthetize skin/subcutaneous tissue
    - Parietal pleura sensitive
      - Estimate depth to pleura based on imaging
      - Administer deep anesthesia to parietal pleura
      - If fluid aspirated during deep anesthesia, confirms that anesthetic applied to pleura; also allows estimation of depth
  - **Diagnostic thoracentesis**
    - Advance 18- to 22-g spinal needle until fluid can be aspirated from pleural space
    - Note color and opacity of aspirated fluid
    - Collect sufficient volume of fluid for requested laboratory analyses
  - **Therapeutic thoracentesis**
    - Nick skin with #11 scalpel blade at entry site
    - Use 7-Fr curved-tip catheter loaded on trocar, attach 10-cc syringe
    - Aspirate while advancing catheter-trocar assembly to pleural space
      - Real-time US guidance may be helpful
    - Pleural puncture delineated by "pop"
    - Once fluid aspirated into syringe, unscrew catheter from trocar; advance catheter off of trocar 2-3 cm into pleural space
      - Do not withdraw trocar until catheter advanced slightly into pleural space; catheter may still be outside of pleura when 1st aspirate seen in syringe
      - Do not hub catheter completely in skin, only advance 2-3 cm past point when fluid was aspirated
      - Placing hand on patient's back will help steady catheter-trocar in space
    - Attach 3-way stopcock and extension tubing
    - If requested, obtain diagnostic specimens by withdrawing fluid via 3-way stopcock
    - Attach tubing to vacuum-drainage bottles
    - Remove appropriate pleural fluid volume
      - Large-volume thoracentesis (> 1 L) avoided in past; fear of reexpansion pulmonary edema
      - Now know large effusions can be safely drained
      - Large-volume thoracentesis may increase pneumothorax risk
- **Chest tube placement**
  - Consider CT for treating pneumothorax/lung abscess/loculated pleural effusions
  - Consider US for pleural effusions
  - Performed similarly to therapeutic thoracentesis
  - After making dermatotomy, perform blunt dissection using hemostat
  - Estimate depth and trajectory to pleural collection
  - **Direct trocar technique**
    - Load 8- to 16-Fr (10-12 Fr typically) pigtail catheter on sharp trocar
    - Advance catheter-trocar assembly while aspirating, may use real-time US
    - Pleural puncture delineated by "pop" and collection of aspirate
    - Unscrew catheter from trocar; advance catheter off of trocar into pleural space
  - **Seldinger technique**
    - Advance 18-g access needle (trocar), may use real-time US
    - Aspirate small amount of fluid
    - Advance 0.035" J-tip guidewire, may use fluoroscopy or US
    - Dilate tract over guidewire to selected catheter diameter
    - Load 8- to 16-Fr (10-12 Fr typically) pigtail catheter on stiffening cannula
    - Advance catheter & stiffening cannula assembly over guidewire into collection, estimate depth, measure depth if using CT, or visualize real-time with fluoroscopy/US
    - Unscrew inner stiffener; hold stiffener so it does not advance
    - Advance catheter further into collection over guidewire, far enough so that last catheter drainage hole is within collection
    - Remove stiffener and guidewire
  - Confirm pigtail position with CT/US
  - Attach 3-way stopcock and extension tubing
  - Collect laboratory specimen through 3-way stopcock
  - Attach extension tubing to water-seal (Pleur-evac) system
  - Secure tube connection with tape to prevent inadvertent disconnection
  - Pleur-evac may be connected to wall suction (-20 cm H_2O)
  - Chest tube fixation
    - Suture catheter directly to skin
    - Adhere tubing to skin with bandages
- **Tunneled pleural catheter**
  - Identify appropriate intercostal pleural access space
    - Typically 6th-7th, anterolateral
  - Identify catheter skin exit site along same intercostal space
    - 5-10 cm from pleural access
    - Anesthetize tract
  - Achieve percutaneous access to pleural space, above rib, advancing needle & introducer
  - Advance J-tip guidewire into pleural space through introducer
  - Make 1-cm incision at pleural access and skin exit sites
  - Tunnel catheter from skin exit to pleural access sites until cuff centered in tunnel
  - Dilate pleural access tract, place peel-away introducer over wire

  - Remove guidewire & introducer, place finger over sheath (do not pinch sheath)
  - Advance catheter through peel-away sheath
  - Remove/peel-away sheath
  - Suture/glue dermatotomy at pleural access site
- **Lung abscess**
  - Referred for percutaneous drainage if failed medical therapy/postural drainage
  - CT guidance is modality of choice
  - Seldinger technique, as with chest tube placement
  - Safest path chosen on preliminary CT images
    - Minimize traversal of lung parenchyma
    - Preferable to enter collection through component that abuts pleura, if possible
  - 8- to 14-Fr catheter typically used

Findings and Reporting

- Note color and opacity of fluid aspirated
- Indicate volume of fluid removed
- Document any complications

Alternative Procedures/Therapies

- Surgical
  - Surgical chest tube placement
- Other
  - Thoracentesis performed using anatomic landmarks

POST PROCEDURE

Things to Do

- **Thoracentesis**
  - Chest radiograph (CXR) to assess for pneumothorax
    - Serial CXR if asymptomatic pneumothorax
      - ☐ Discharge if small and stable/resolving
      - ☐ Chest tube and admission if enlarging pneumothorax/symptomatic patient
- **Chest tube**
  - Place chest tube to wall suction (-20 cm H_2O)
  - Obtain chest radiograph, postprocedure & daily
  - Record drain output q shift
  - Flush catheter with 10 mL normal saline q 8-12 hr
  - **Chest tube removal criteria**
    - Clinical improvement
    - Pleural effusion (transudate)
      - ☐ Output ≤ physiologic output (1 mL/kg/day)
      - ☐ Resolved effusion on chest radiograph
    - Pleural effusion (exudate)/empyema
      - ☐ Output ≤ 20 mL/day
      - ☐ Complete drainage on CT
    - Pneumothorax
      - ☐ Place on water seal when no pneumothorax on CXR and no air leak x 24 hr
      - ☐ Clamp tube x 4 hr, repeat CXR
      - ☐ If no pneumothorax on repeat CXR, remove tube
  - **Tunneled Pleural Catheter**
    - Arrange nursing/home health follow-up to instruct proper usage of catheter
    - All effusion must be removed for first 7-10 days in order for cuff to adhere to tunnel
      - ☐ Drain fluid daily until only trace fluid aspirated during drainage, then back off drainage to every other day, every 3rd, ect., as appropriate to achieve goal of comfort

OUTCOMES

Problems

- Incomplete drainage by chest tube
  - Disruption of pleural septations
    - 5 mg tPA + 5 mg DNase in 25-50 mL sterile 0.9% saline
    - Instill solution into cavity; clamp chest tube x 30 min
    - Unclamp and resume chest tube drainage
    - Repeat 2x daily for 3 days
    - Perform chest CT after cycle to assess response
    - May consider repeating cycle if incomplete drainage
    - Prophylactic anticoagulation for deep venous thrombosis not contraindication
    - Therapeutic anticoagulation is relative contraindication due to intrapleural hemorrhage risk
  - Multiple loculated collections
    - Additional chest tubes may be required
- Air leak
  - Signified by air bubbles in Pleur-evac chamber
  - Inspect catheter/tubing to assess
    - Inadvertent disconnection
    - Whether chest tube has been pulled out
  - Chest radiograph to assess for pneumothorax and chest tube position
  - Consult thoracic surgery if bronchopleural fistula suspected
    - Prolonged air leaks may require watchful waiting
    - Some may be managed as outpatients with 1-way valve attached to chest tube

Complications

- Thoracentesis: Pneumo/hemothorax
- Chest tube: Dislodgement, chest pain
- Tunneled pleural catheter
  - Leak from skin: Incomplete drainage
  - Catheter not draining
    - Blocked lumen, flush with saline to clear
    - Little residual pleural fluid, remove catheter
    - Loculated pleural effusion
- Lung abscess drain: Bronchopleural fistula

Expected Outcomes

- Chest tube
  - > 80% success treating pleural effusion and pneumothorax
- Lung abscess drainage
  - > 70% success after 10-15 days of drainage
- Tunneled pleural catheter
  - Spontaneous pleurodesis occurs 40% of cases, allowing removal of catheter

SELECTED REFERENCES

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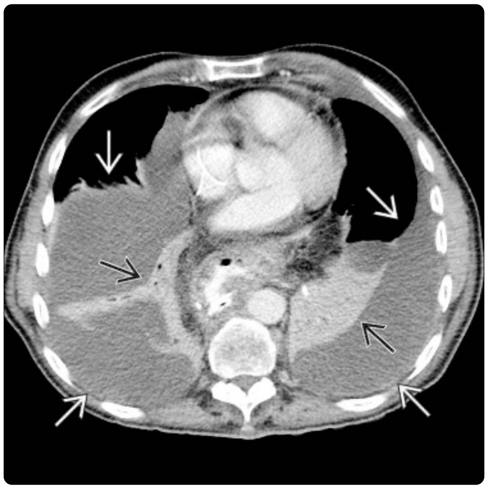
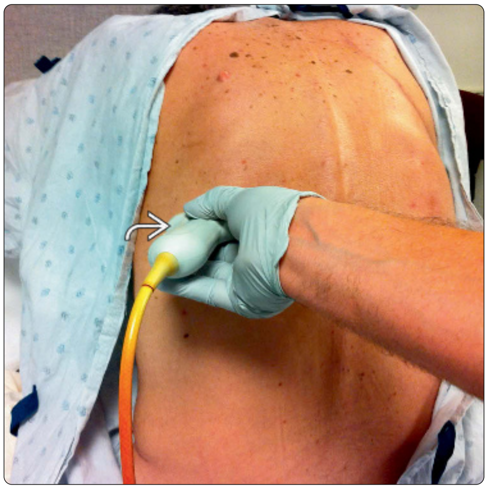
2. Merritt RE et al: Evidence-based suggestions for management of air leaks. Thorac Surg Clin. 20(3):435-48, 2010

(Left) *Axial CECT obtained in a postoperative patient shows large bilateral pleural effusions* ➡ *and associated compressive atelectasis* ⇨*. Thoracentesis may determine if these are malignant pleural effusions and may also be therapeutic in improving aeration.* **(Right)** *The patient is positioned on the side of a stretcher with the arms folded on a table for support. US* ↪ *of the left pleural space is used to locate intercostal access for chest tube placement.*

Thoracentesis Procedure (Preprocedure Imaging)

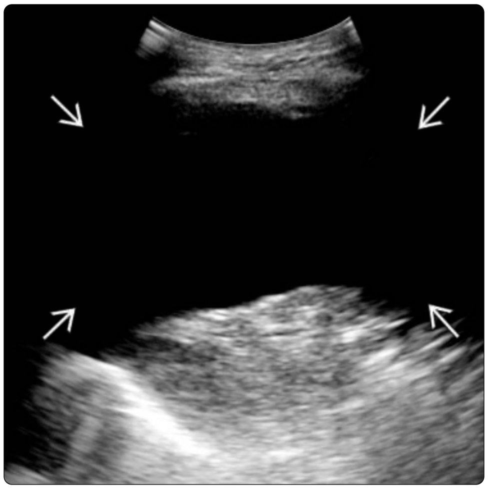


Thoracentesis Procedure (US Localization)

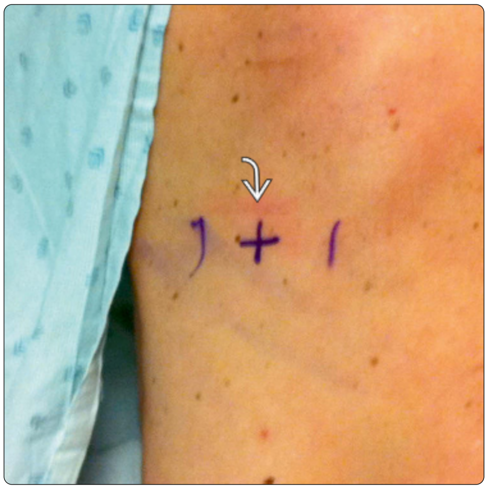


(Left) *Axial US of the left pleural space demonstrates a large, anechoic area in the lung base, corresponding to a large pleural effusion* ➡*. This will serve as the target for chest tube placement, which will be performed using US for imaging guidance.* **(Right)** *Following the ultrasound evaluation of the pleural effusion, the skin has been marked* ↪ *at the intercostal site that has been selected as the access point for percutaneous chest tube placement.*

Thoracentesis Procedure (US Guidance)

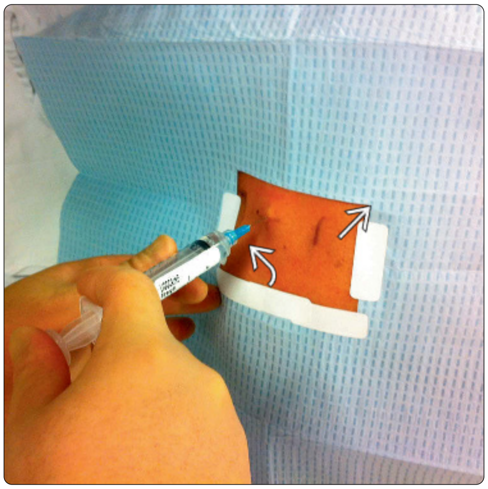


Thoracentesis Procedure (Access Site Selection)

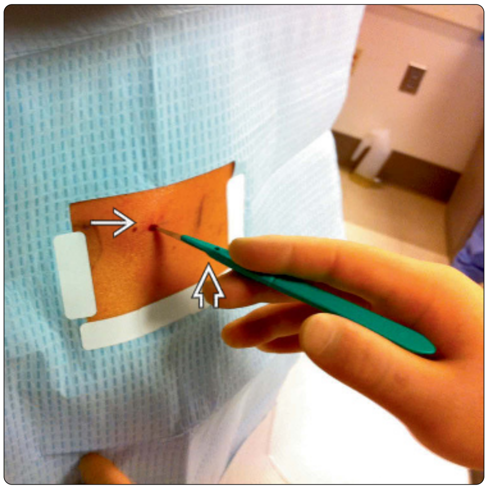


(Left) *The skin is sterilely prepared with chlorhexidine or Betadine and draped* ➡*. A small-gauge needle (e.g., 25 g)* ↪ *is used to administer 1-2% lidocaine to the skin surface and the pleural surface.* **(Right)** *A skin nick is made with a #11 blade scalpel* ⇒ *at the selected skin access point* ➡*. This site will be used to advance a trocar-mounted drainage catheter through the skin and into the pleural fluid collection.*

Thoracentesis Procedure (Access Site Preparation)

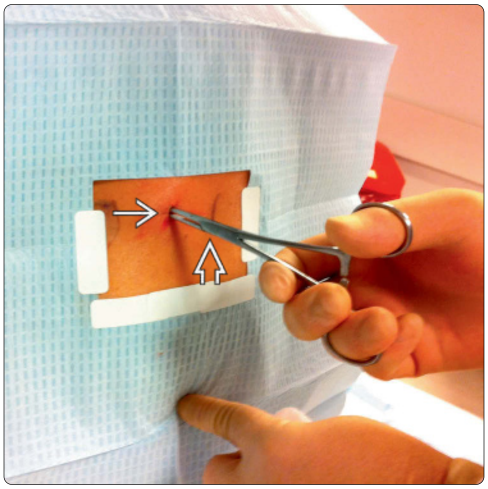


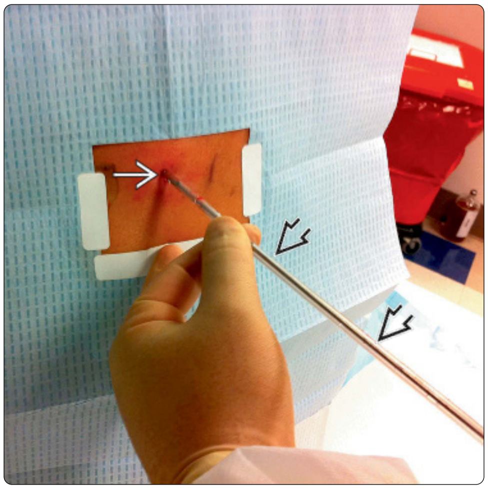
Thoracentesis Procedure (Access Site Preparation)



Thoracentesis Procedure (Access Site Preparation)

Thoracentesis Procedure (Direct Trocar Technique)

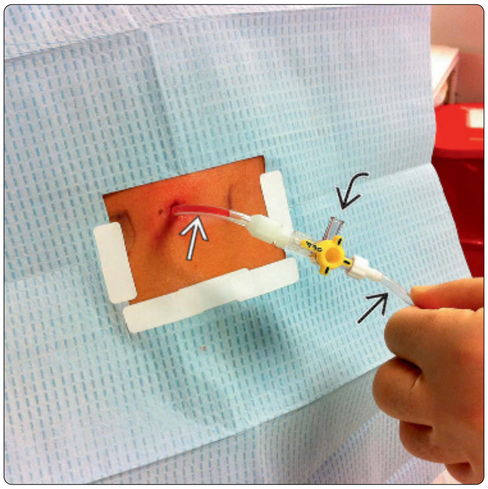




(Left) *A hemostat ➡ has been introduced into the skin nick ➡ that was created by the scalpel and is being used to perform blunt dissection of the subcutaneous tissues.* **(Right)** *A 16-Fr chest tube ⇨ loaded onto a trocar is introduced into the skin nick ➡ and is advanced until a "pop" is elicited, which signifies traversal of the parietal pleura. Pleural fluid may also flow out the sideholes of the catheter. Real-time visualization with US was considered unnecessary due to the large size of the effusion.*

Thoracentesis Procedure (Direct Trocar Technique)

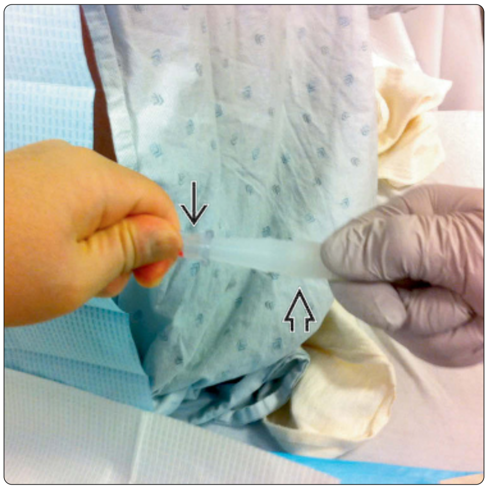
Thoracentesis Procedure (Pleur-evac Collection System)

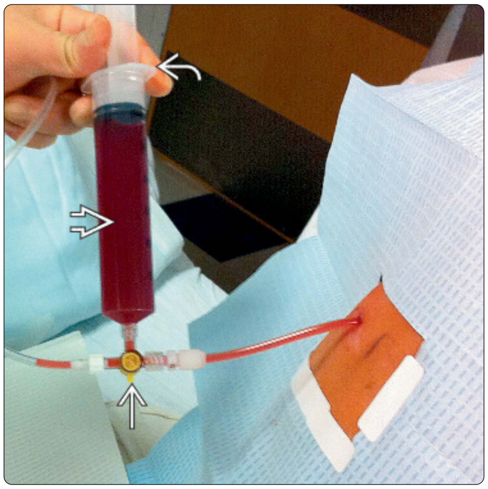


(Left) *Once pleural entry has been achieved, the catheter is unscrewed from the trocar. While holding the trocar in a stationary position, the catheter is advanced off of the trocar into the effusion until all sideholes are within the pleural space. Note the presence of pleural fluid within the catheter ➡. A 3-way stopcock ⇨ and connecting tubing ⇨ are attached.* **(Right)** *A water-seal collection system ➡, containing a calibrated chamber for collecting and quantifying the drained pleural fluid ➡, is prepared.*

Thoracentesis Procedure (Pleur-evac Collection System)

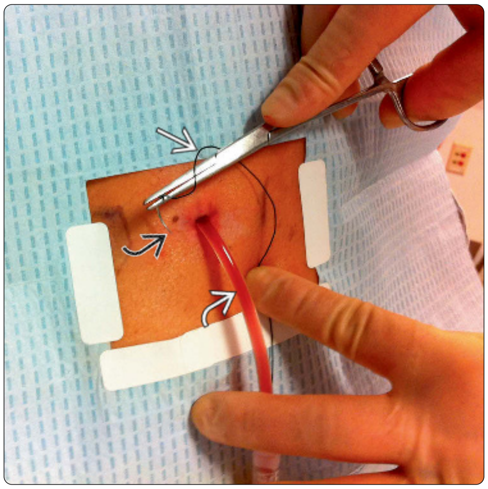
Thoracentesis Procedure (Aspiration of Fluid)



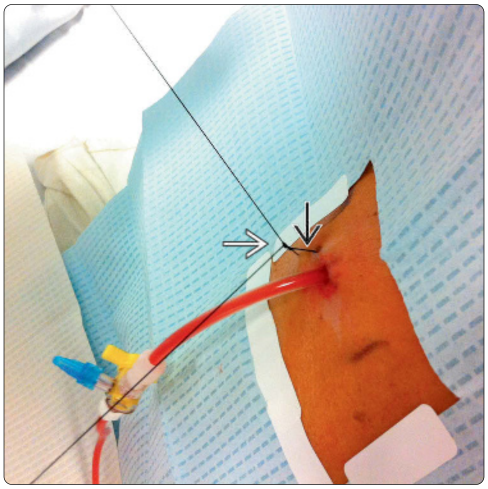


(Left) *The water-seal collection system ⇨ is securely connected to the extension tubing ⇨ from the chest tube.* **(Right)** *After connecting the tubing, a 20-mL syringe ➡ is connected to a port on the 3-way stopcock ➡, and 1 or more samples of pleural fluid ➡ are withdrawn and sent for laboratory analysis. One should ensure that the volume of pleural fluid collected is sufficient for the requested laboratory analyses. The color and consistency of the aspirated fluid should be noted in the procedural report.*

(Left) *The catheter is affixed directly to the skin in order to prevent its accidental dislodgement. Commercially available fixation devices are available for securing the catheter. In this example, a suture* ➡ *is used to directly secure the catheter. The suture is placed through a skin site lateral* ↷ *to the catheter* ↪ *and the insertion site.* **(Right)** *Intraprocedural photograph shows that several knots* ➡ *have been tied over an "air knot"* → *that was initially tied after anchoring the suture through the skin.*

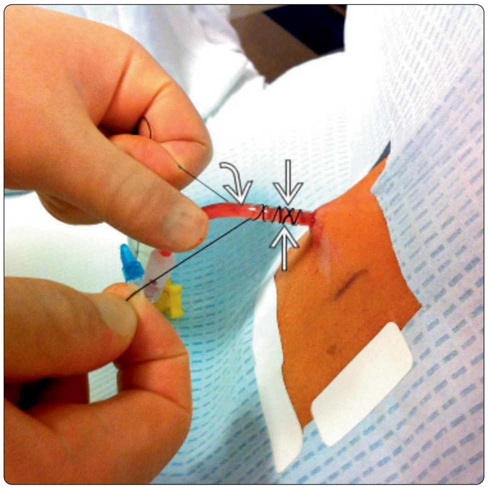


Thoracentesis Procedure (External Fixation of Catheter)

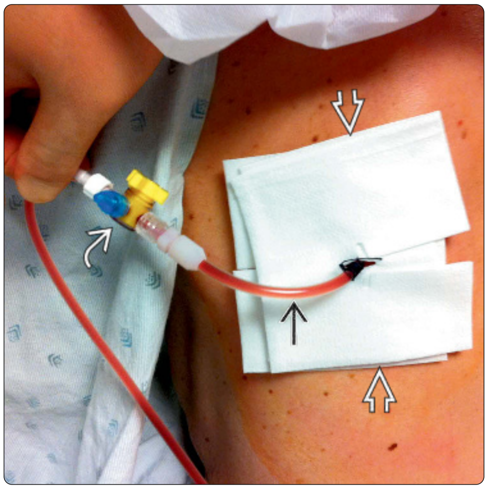


Thoracentesis Procedure (External Fixation of Catheter)

(Left) *The 2 free ends of the suture are subsequently wrapped tightly around the catheter* ↪ *multiple times* ➡ *and tied; the excess suture length is then trimmed. One should ensure that the tied suture does not crimp the catheter and thereby limit the fluid drainage.* **(Right)** *After securing the catheter, the skin is cleansed with hydrogen peroxide and several drain sponges* ⇨ *are applied around the catheter* →*. Note the catheter is directed laterally so that the patient will not lie on the tubing or the stopcock* ↪ *when supine.*

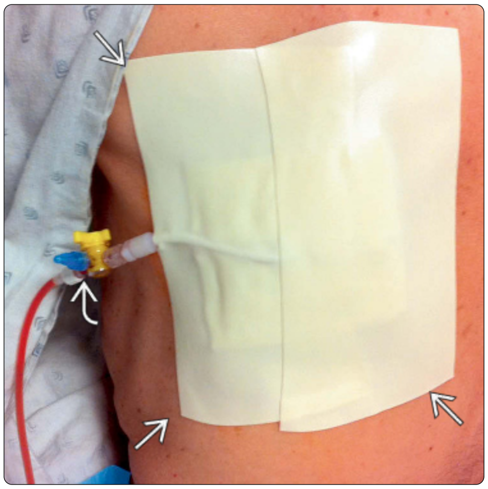


Thoracentesis Procedure (External Fixation of Catheter)

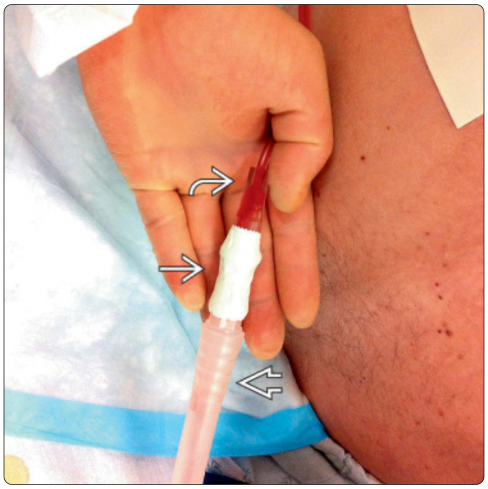


Thoracentesis Procedure (Catheter Site Dressing)

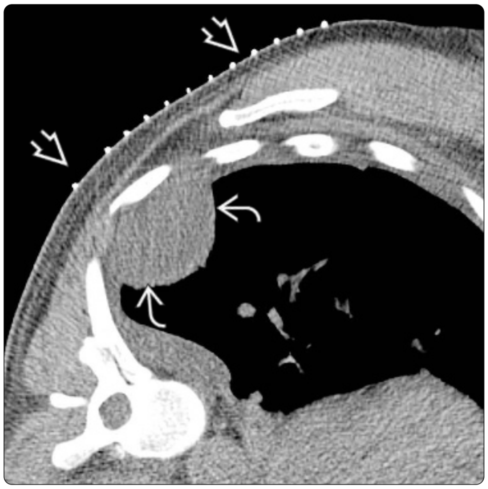
(Left) *After placing the drain sponges, an adhesive protective bandage* ➡ *is securely applied, taking care to preserve access to the 3-way stopcock* ↪ *so that regular catheter flushing may be performed. The catheter is usually flushed with 10 mL of normal saline every 8-12 hr to prevent clogging. More frequent flushes may be necessary if the fluid is tenacious.* **(Right)** *The connection between chest tube* ↪ *and the Pleur-evac collection system* ⇨ *is taped* ➡ *to reduce the risk of inadvertent disconnection.*



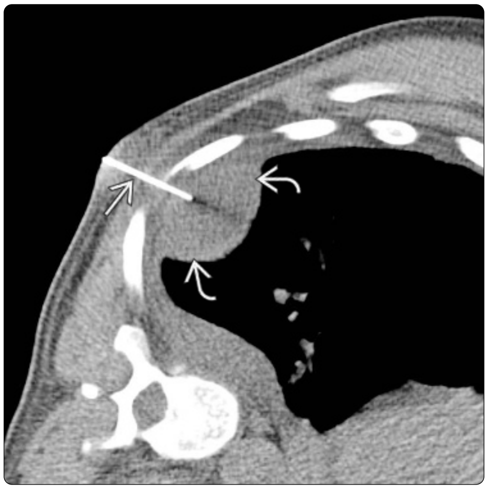
Thoracentesis Procedure (Catheter Site Dressing)



Thoracentesis Procedure (Secured Tubing)

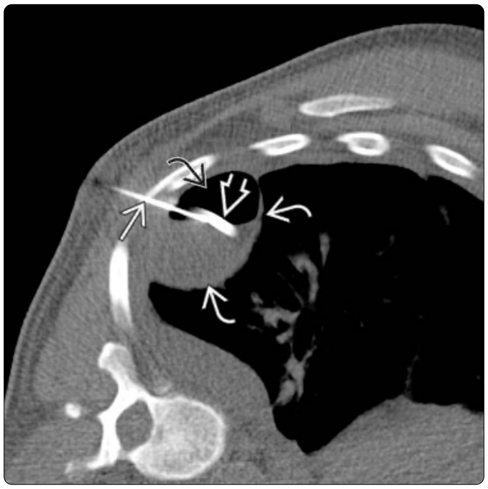


CT-Guided Thoracic Drainage (Initial Localization)

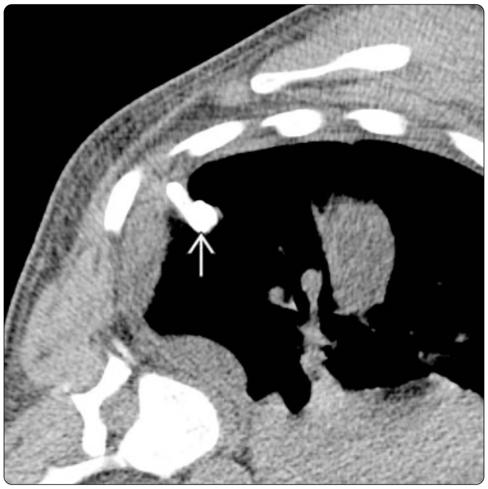


CT-Guided Thoracic Drainage (Tandem Trocar Technique)

(Left) *With the patient in the lateral decubitus position, a grid with radiopaque lines* ➔ *has been placed posteriorly on the skin overlying a lenticular-shaped loculated pleural collection* ➔. *The grid will be used to select the most appropriate skin entry point for catheter placement.* **(Right)** *With intermittent CT guidance (or CT fluoroscopy), a 20-g guiding needle* ➔ *is advanced into the collection* ➔ *to the depth that was determined by measurements made on the preliminary images.*

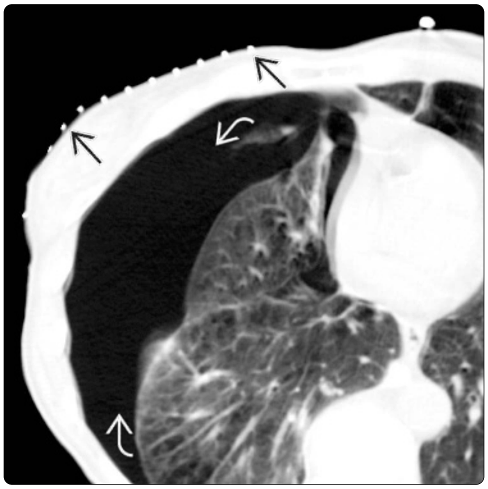


CT-Guided Thoracic Drainage (Tandem Trocar Technique)

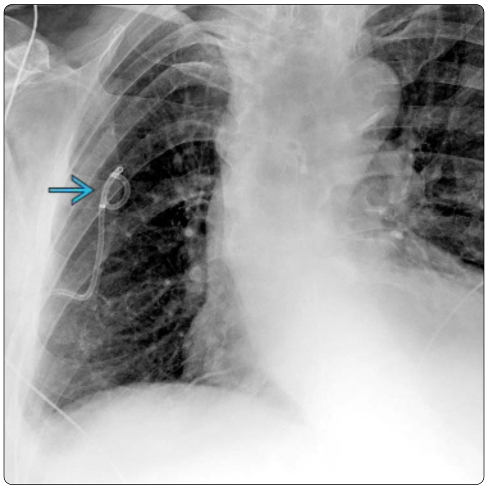


CT-Guided Thoracic Drainage (Confirmation of Catheter Position)

(Left) *The catheter* ➔ *has been advanced off of the trocar and into the collection* ➔ *in tandem with the initially placed guiding needle* ➔. *There is now a small volume of air* ⇨ *within the collection, as a sample of the loculated pleural fluid has been aspirated.* **(Right)** *Following removal of the initially placed guiding needle and aspiration of the loculated fluid, CT shows the tip* ➔ *of the catheter within the collapsed cavity. It is important to document the final catheter position.*



Iatrogenic Pneumothorax (Localizing Access Site for Drain Placement)



Iatrogenic Pneumothorax (Post Drain Placement)

(Left) *Initial imaging during a CT-guided chest tube placement shows a grid with radiopaque lines* ⇨ *overlying the anterolateral right pleural space. A very large right pneumothorax* ➔ *is seen, which occurred during an US-guided diagnostic thoracentesis.* **(Right)** *A 10-Fr pigtail chest tube was placed and attached to water seal. Subsequent radiograph shows resolution of the pneumothorax. The drain* ⇨ *is properly positioned in the nondependent, anterior pleural space.*

Thoracic Biopsy

KEY FACTS

PREPROCEDURE

- Indications
  - Thoracic mass, nodule, or consolidation
    - Establish primary malignancy vs. benign disease
    - Confirm metastasis, stage malignancy
    - Obtain tissue for molecular profiling/genomic analysis
    - Obtain material for microbiologic analysis
    - Repeat nondiagnostic bronchoscopic biopsy

PROCEDURE

- **General**
  - Determine best access route: Shortest path, minimize pleural transgression, avoid vessels, bronchi, fissures, blebs and bullae
  - Fine needle aspiration ± core biopsy
  - Typically use coaxial-needle technique
  - Modalities: CT, CT fluoroscopy, fluoroscopy, fluoroscopic cone-beam CT, ultrasound
  - CT fluoroscopy: May decrease complication rates, but increase radiation exposure to patient and proceduralist
  - US: Best for chest wall, mediastinal, subpleural masses
    - Doppler vessels along path or within target

POST PROCEDURE

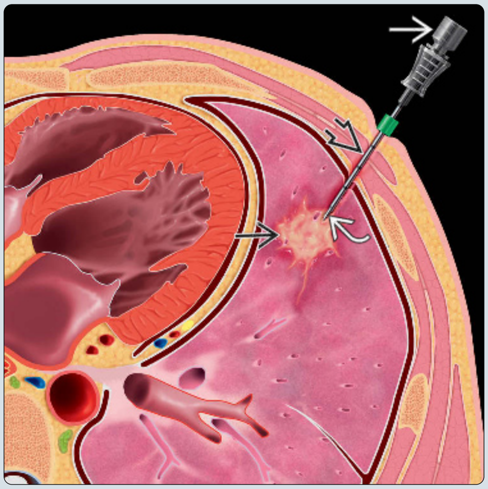
- After needle removal, place patient biopsy-side down
- CXR immediately and 2-4 hours after biopsy

OUTCOMES

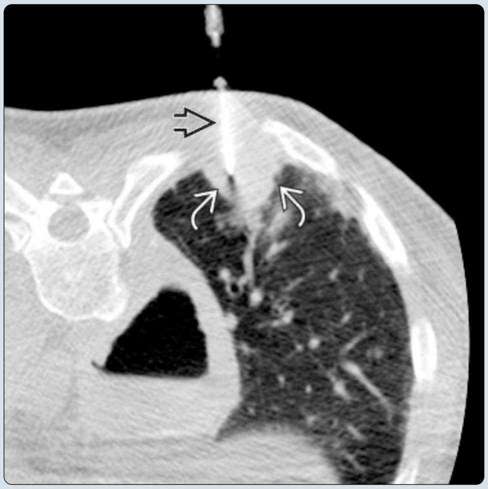
- Reported accuracy: 77-96%,
  - Combined FNA & core biopsy, 95.2% diagnostic accuracy
  - Accuracy improved by on-site cytopathology
- Complications
  - Pneumothorax: Overall reported rate = 17-27%; requiring chest tube = 1-14%
  - If pneumothorax large or enlarging, or patient symptomatic, place chest tube
  - Hemoptysis reported rate = 4%

(Left) *Graphic shows an introducer needle ⇨ positioned with the tip ↪ at the edge of a lung mass →. The sharp inner stylet → of the needle is still in place and will be removed to allow introduction of a biopsy needle into the mass.* **(Right)** *Axial image from a CT-guided percutaneous needle biopsy of a pleural-based pulmonary mass ↪ shows that an introducer needle ⇨ has been advanced into the mass. Pathology demonstrated small cell lung carcinoma.*

Percutaneous Lung Biopsy

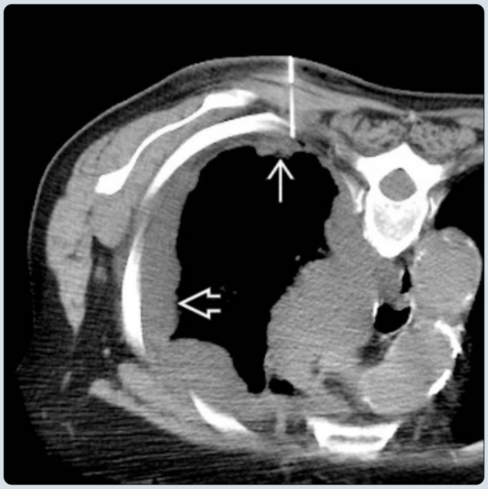


CT-Guided Percutaneous Biopsy of Subpleural Nodule

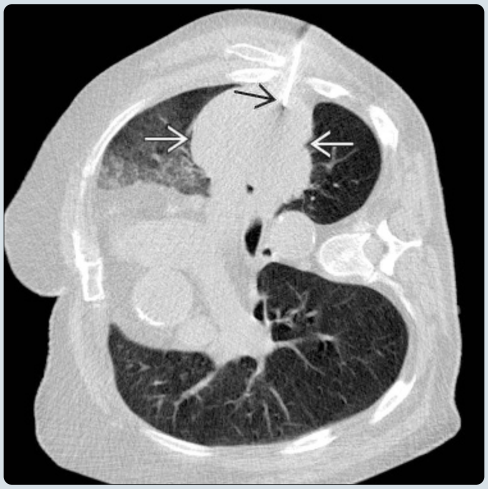


(Left) *CT is ideal for targeting pleural-based masses, as seen in this patient with pleural masses → and a lobulated pleural effusion ⇨. Metastatic non-small cell carcinoma was diagnosed.* **(Right)** *Minimize procedural radiation by limiting kVp and mAs (and the number of slices obtained with each scan). This image was obtained with 19 mAs and 120 kVp, less dose than used in a typical lung screening exam. The minimally decreased image resolution in no way impairs the procedure; the mass → and biopsy needle → are clearly seen.*

Pleural Based Mass



Low-Dose CT Imaging During Biopsy



PREPROCEDURE

Indications

- Thoracic mass, nodule, or consolidation
  - Establish primary malignancy vs. benign disease
  - Confirm suspected metastatic disease
  - Stage known malignancy
  - Obtain tissue for molecular profiling & genomic analysis
  - Obtain material for microbiologic culture
  - Repeat nondiagnostic bronchoscopic biopsy

Contraindications

- Uncooperative patient
- Pulmonary arteriovenous malformation, varix
- Echinococcal cysts (risk of anaphylaxis)
- Relative contraindications
  - Severe emphysema or interstitial lung disease (single largest predictor of postbiopsy pneumothorax)
  - Uncorrectable bleeding diathesis
  - Lack of safe access path to lesion
  - Severe pulmonary arterial hypertension
  - Positive pressure ventilation
  - Contralateral pneumonectomy
  - Accessible extrapulmonary disease
  - Bronchoscopically accessible lesions (typically central lesions adjacent to large vessels/bronchi)
- Nodule size < 1 cm not necessarily contraindication

Preprocedure Imaging

- CT chest, generally required
  - Assess whether target suitable for percutaneous biopsy
    - Peripheral lesions generally more suitable for percutaneous biopsy
    - Central peribronchial lesions may be amenable to bronchoscopy
    - Small basilar nodules may be better suited for video-assisted thoracoscopic biopsy (VATS)
  - Presence of extrapulmonary lymphadenopathy, adrenal or liver lesions
    - May allow safer biopsy, diagnosis, and staging simultaneously
- PET/CT, review if available
  - Target areas of increased activity within lesion

Getting Started

- Things to check
  - Pertinent clinical history and physical examination
    - Procedure indications
    - Allergies
    - Medications, withhold systemic anticoagulants
      - Lung biopsy is considered to have moderate risk of bleeding
      - Hold aspirin 5 days prior to procedure
      - Hold oral anticoagulants & switch to IV heparin, discontinue several hours prior to procedure
      - Consensus guidelines set forth by Society of Interventional Radiology (2013)
  - Laboratory parameters
    - Complete blood count recommended
      - Platelet > 50,000/μL
    - Coagulation profile recommended
      - International normalized ratio (INR) ≤ 1.5
      - Activated partial thromboplastin time (aPTT) ≤ 1.5
  - Informed consent
    - Discuss potential pneumothorax, hemorrhage/hemoptysis
    - Consider discussing false-negative biopsy results in challenging cases, and possible chest tube placement
- Medications
  - Anesthesia
    - 1% lidocaine local anesthetic
  - Procedural sedation
    - Fentanyl, midazolam typically used
- Equipment list
  - Computed tomography (CT)
    - Primary imaging guidance modality
    - Allows correlation with available PET
    - Visualize intervening chest wall structures & vessels
      - Internal mammary, subclavian artery
    - Visualize intervening lung structures & vessels
      - Normal lobar fissures, bronchi, vessels
      - Hypertrophied vessels supplying target
      - Enhances precision of needle trajectory
    - CT Fluoroscopy
      - Allows real-time visualization of needle placement and adjustments
      - Advantageous for highly mobile lesions
      - Decreases procedure time
      - May decrease complication rates
      - Increases radiation exposure to patient and proceduralist
  - Fluoroscopy
    - Used less frequently than previously
    - Suitable for large nodules/masses visible in at least 2 projections
    - Allows real-time visualization of needle placement and adjustments
    - Smaller lesions not well demonstrated
    - Fluoroscopic cone-beam CT
      - Allows real-time visualization of needle placement and adjustments during fluoroscopy
      - Allows cross-sectional imaging to verify needle position
      - Decreases case burden on diagnostic CT scanner
  - Ultrasound (US)
    - Appropriate for chest wall and large pleural lesions
    - Allows real-time visualization of needle placement and adjustments
    - Aerated lung inhibits US visualization
    - Pulmonary nodules generally poorly delineated
  - Biopsy needles
    - Coaxial technique minimizes number of passes through pleura/tissues overlying lesion
      - 19-gauge introducer needle
      - FNA: 20-22-gauge aspiration needle (e.g., Chiba)
      - Core: 20-gauge core biopsy gun
    - Sterile saline solution (microbiology)
    - Formalin solution (pathology)
    - Roswell Park Memorial Institute (RPMI) solution for flow cytometry if concern for lymphoproliferative disease

  - Request on-site cytopathology

PROCEDURE

Procedure Steps

- **General**
  - Review preliminary images; target
    - Periphery of cavitary lesions
    - PET-positive component of lesion
    - Solid component of part-solid lesions
  - Determine best access route
    - Avoid chest wall vessels, e.g., internal mammary, subclavian, intercostal
    - Shortest path, minimize pleural transgression
    - Minimize crossing fissures (puncture pleura only once)
    - Avoid bullae, bronchi, intrapulmonary vessels
    - Angled trajectory has higher risk of pneumothorax
    - Consider transgressing normal lung to biopsy subpleural lesions
      - Minimizes number of pleural punctures
      - Lesion will not push away from biopsy device
  - Position patient
    - Prone approach preferred over supine when possible
      - Reduced respiratory motion
      - Posterior interspaces wider than anterior interspaces
      - Patient unable to visualize needle
      - To minimize scapula interference, place arms by patient's side, internally rotate
    - Decubitus/oblique position occasionally necessary
      - May be appropriate for some deep lesions
      - Patient position less stable
      - Higher risk of pneumothorax
    - Angling gantry may be necessary
      - Avoidance of lung fissures
      - Negotiation of intercostal space
  - Coaxial vs. single-pass technique
    - Coaxial often preferred to reduce pleural punctures
    - At least one study shows no difference in complication rates
  - FNA vs. core biopsy vs. combined FNA & core
    - FNA: Diagnostic accuracy: 85.1% for malignant tumors, 40% for benign-specific tumors
    - Core: Diagnostic accuracy: 86.7% for malignant tumors, 92% for benign-specific tumors
      - Slightly higher rate of complications vs. FNA
      - Not recommended for lesions < 10 mm
    - Combined FNA & core: 95.2% diagnostic accuracy
      - Benefit when malignancy likely, and in establishing specific benign diagnosis
  - Breathing Instructions
    - Breath hold
      - Most applicable for lower lobe/mobile lesions
      - Request small inspiration, then hold
      - Repeat during scan & needle positioning
      - Less sedation can be given
    - Normal respiration
      - Expiratory phase longer than inspiratory phase
      - Assume scan occurs during exhalation (if lesion seen to move, rescan)
      - Adjust needle/biopsy immediately after exhalation
      - Allows for more patient sedation
- **CT guidance**
  - Place localizing radiopaque grid on skin, based on prior studies
  - Obtain preliminary images
    - Compare target vs. appearance on prior studies
      - Infectious/inflammatory nodules may have decreased in size or disappeared at time of procedure, obviating need for biopsy
  - Select skin entry site on grid; mark with pen
  - Sterilely cleanse and drape skin
  - Administer 1% lidocaine to skin and pleura
  - Nick skin with #11 scalpel blade
  - Advance 19-gauge introducer needle into tissues superficial to pleura
    - Make needle adjustments while in superficial tissues
    - Obtain CT after each needle adjustment
  - When needle angle appropriate for planned trajectory, decisively advance needle through pleura
  - Make additional needle adjustments as necessary
    - Avoid withdrawing needle through pleura
    - Angle needle slightly more than seems necessary (needle tip will angle less than hub due to bend as needle passes through chest wall)
    - Measure distance to lesion, advance sharply
  - Confirm needle tip at lesion periphery
  - Remove stylet, cover needle with saline or finger
  - Perform FNA
    - Attach 10 mL syringe to 22-gauge FNA needle
    - Advance 22-gauge FNA needle via introducer needle
    - Jiggle needle with to-and-fro motion while applying suction to syringe
    - Avoid suctioning blood products during needle removal
    - 2-3 needle passes, or dependent by smears from on-site cytopathologist
    - Place specimen onto glass slide, or hand to cytopathology representative
      - Additional sample in sterile saline/RPMI for flow cytometry (suspected lymphoma)
      - Aspirate sample in sterile saline for microbiology (suspected infection)
  - Core biopsy
    - Perform in addition to FNA if
      - Requested by cytopathology representative upon evaluation of FNA specimens
      - Need subtyping of specific malignancies (e.g., lymphoma, neuroendocrine tumor)
      - Benign diagnosis suspected
    - Understand operation of chosen biopsy device
      - Usually automated, spring-activated, side-cutting device
    - Confirm needle tip at lesion, observe adjacent structures, calculate biopsy throw
    - Activate ("fire") biopsy gun
    - Place sample in sterile saline
    - 2-4 needle passes, or dependent by touch preps by on-site cytopathologist
  - Apply dressing

- **US guidance**
    - For larger pleural, chest wall, or subpleural masses
    - Image target
        - Doppler to assess for intervening vessels along path or within target
        - Watch for motion of lesion
        - Reconfirm planned needle trajectory
    - Prep skin, perform biopsy as above

Findings and Reporting

- Describe size and location of biopsied target
- Specify FNA, core biopsy, or combination FNA and core biopsy
- Periprocedural complications and response

Alternative Procedures/Therapies

- Surgical
    - VATS biopsy
    - Open biopsy
- Other
    - Bronchoscopic biopsy

POST PROCEDURE

Things to Do

- After removal of introducer needle, place patient biopsy-side down
    - Supine position if prone biopsy performed
    - Patient weight on biopsy site reduces risk of air leak/pneumothorax
- Discourage coughing & talking during recovery period
- Continue supplemental oxygen by nasal cannula
- Obtain upright chest radiograph immediately & 2-4 hours after biopsy
    - Assess for pneumothorax

OUTCOMES

Complications

- Pneumothorax
    - Usually small and asymptomatic
        - Overall reported rate = 17-27%
        - Requiring chest tube = 1-14%
    - Associated factors and risk of pneumothorax: Lesion size, lesion depth, experience of proceduralist, number of pleural punctures, nonperpendicular needle angle to pleura, presence of chronic obstructive pulmonary disease
    - Treatment
        - Intraprocedural pneumothorax
            - ☐ Consider 2nd needle placement to aspirate air
        - Pneumothorax at completion of biopsy
            - ☐ Aspirate pleural air while withdrawing needle
        - Postprocedural pneumothorax
            - ☐ Large pneumothorax, increasing size, or patient symptomatic: Place chest tube
            - ☐ Supplemental oxygen may help facilitate resorption of pneumothorax
- Pulmonary hemorrhage
    - Perilesional ground-glass opacity
        - Reported rate = 4-27%
    - Hemoptysis
        - Reported rate = 4%
        - Higher rate when lesion < 2 cm, needle path > 4cm
        - Reassure patient, as often resolves
        - Treatment
            - ☐ Terminate procedure, remove needles
            - ☐ Place lateral decubitus position, biopsy-side down (prevents blood aspiration into contralateral lung)
            - ☐ Suction airway
            - ☐ Consider thoracic surgery/pulmonary consult for bronchoscopic clearance of blood products
- Air embolism
    - Reported rate = 0.06% (extremely rare)
    - Result of needle traversing pulmonary vein during patient inspiration
    - Occlude biopsy needle with inner stylet, syringe, saline drops, or finger
    - Treatment
        - Place in left lateral decubitus position
        - Deliver supplemental oxygen
- Hemothorax: Reported rate = 1.5-2.5%
- Tumor seeding: Reported rate = 0.01-0.06%

Expected Outcomes

- Overall reported accuracy of percutaneous biopsy (77-96%)
    - Increased by
        - On-site cytopathology
        - Combination FNA & core biopsy
    - Decreased by
        - Longer needle path
        - Lesion size <15 mm (sampling error) or > 5 cm (necrosis)
- FNA
    - Diagnostic accuracy: 85% for malignant tumors, 40% for benign-specific tumors
    - Sensitivity (82-99%); specificity (86-100%)
    - Low false-positive result (0-0.2%)
    - Variable false-negative result (6-54%)
- Core biopsy
    - Diagnostic accuracy: 87% for malignant tumors, 92% for benign-specific tumors
    - Sensitivity (89%); specificity (97%)
- Combined FNA & core: 95.2% diagnostic accuracy
- Modality: Similar diagnostic accuracy rates with fluoroscopy, cone-beam CT vs. CT
- Repeat biopsies: 50% of initially nondiagnostic samples yield diagnosis

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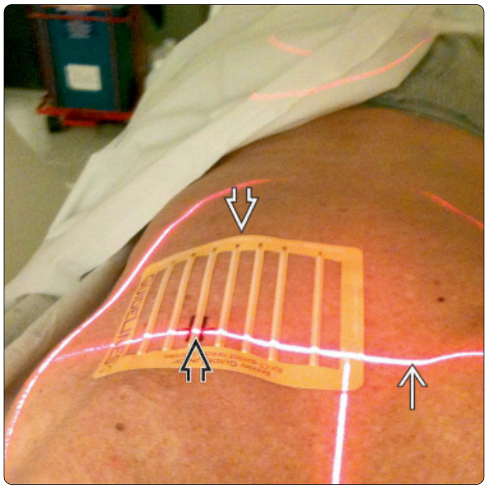
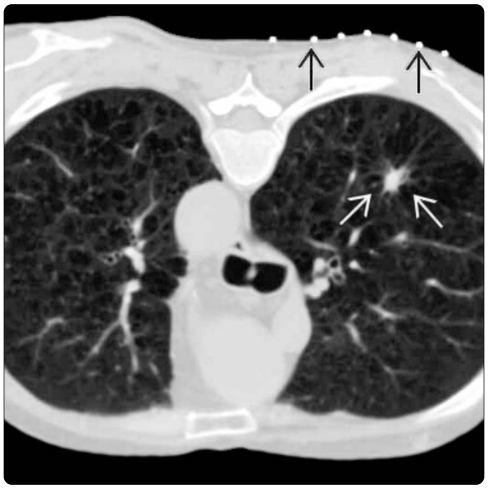
(Left) *A localizing grid ➡ with radiopaque lines has been placed posteriorly on the skin overlying the target lesion. A site is selected along the radiopaque lines based on the preliminary CT images. A mark ⇨ is made at this location along the red laser line ➡ demarcating the chosen axial slice position.* **(Right)** *With the patient placed prone, axial CT imaging shows the radiopaque markers as points ⇨. This axial image showing the spiculated pulmonary nodule ➡ corresponds to the localizing laser on the skin.*

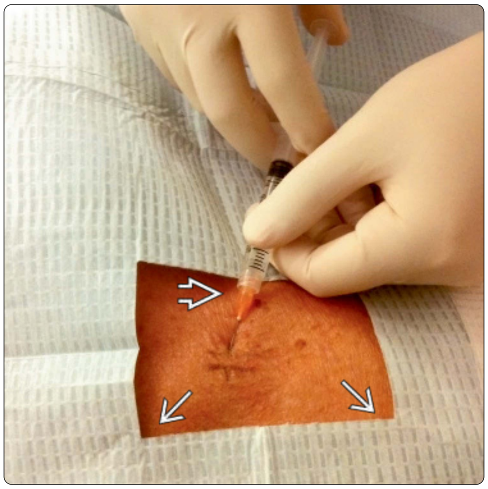


CT-Guided Lung Biopsy (Site Selection for Biopsy)

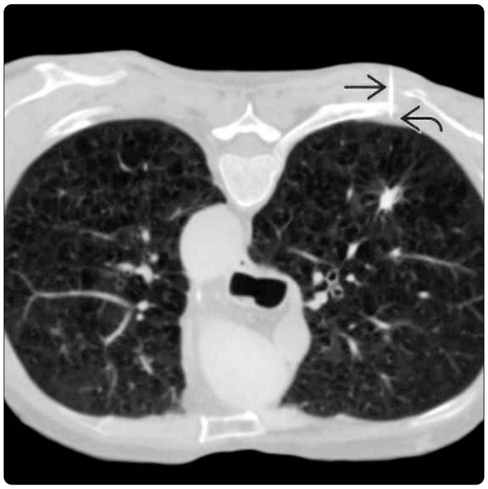


CT-Guided Lung Biopsy (Preliminary Imaging)

(Left) *After the skin has been cleansed with a preparatory solution and a sterile field has been isolated by drapes ➡, 1% lidocaine ➡ is administered as a local anesthetic at the chosen access point.* **(Right)** *Axial NECT shows the introducer needle ⇨ within the soft tissues with the tip ↪ still superficial to the pleura. To limit the risk of pneumothorax, it is important to confirm appropriate needle trajectory, or correct as needed, prior to crossing the pleura.*

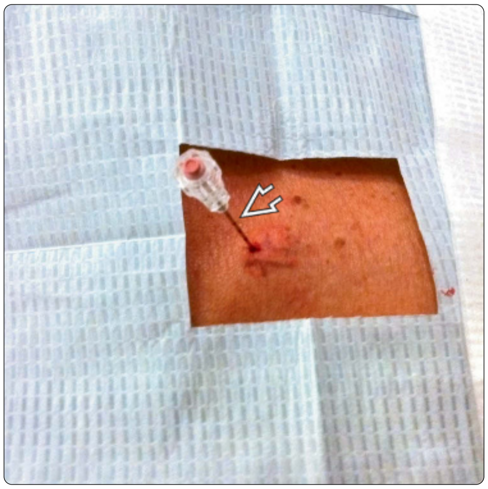


CT-Guided Lung Biopsy (Local Anesthetic)

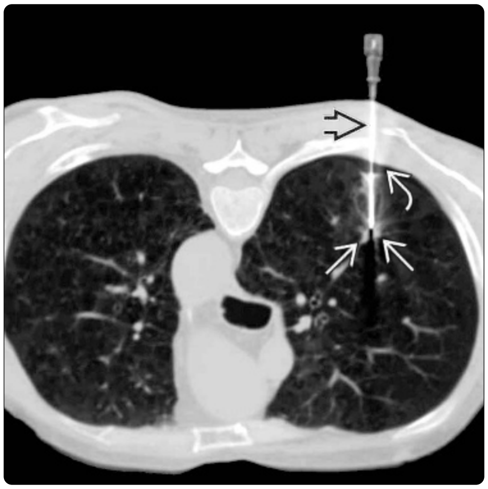


CT-Guided Lung Biopsy (Introducer Needle Placement)

(Left) *Refer to 1-cm markers along the side of the introducer ➡ while it is advanced. Throughout the procedure, ensure that the introducer has not inadvertently advanced or retracted.* **(Right)** *The introducer needle ⇨ is advanced through the pleura ↪ to the edge of the lesion ➡. Subsequently, multiple fine needle aspirates (22-gauge needle) or core biopsies (20-gauge coring gun) may be performed. With coaxial technique, multiple samples may be obtained through a single puncture of the pleura.*

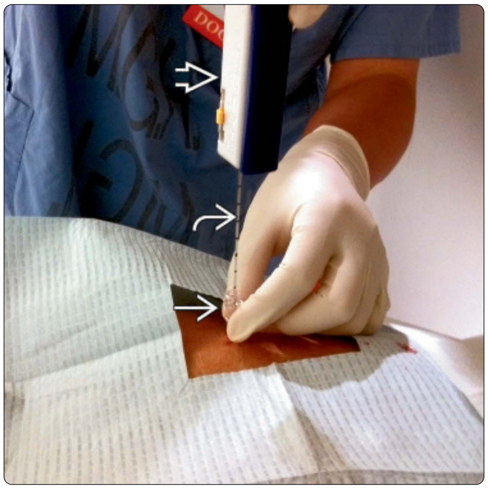


CT-Guided Lung Biopsy (Introducer Needle Placement)

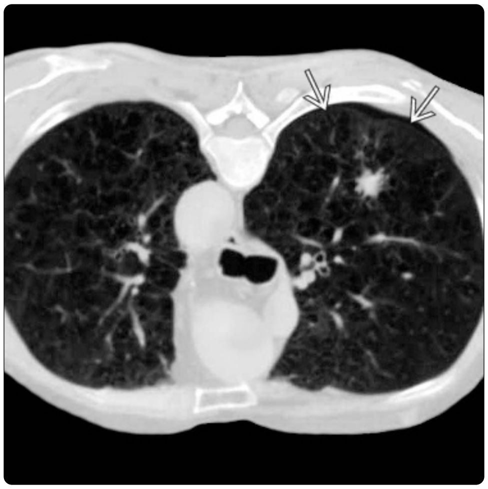


CT-Guided Lung Biopsy (Introducer Needle Placement)

CT-Guided Lung Biopsy (Core Biopsy)

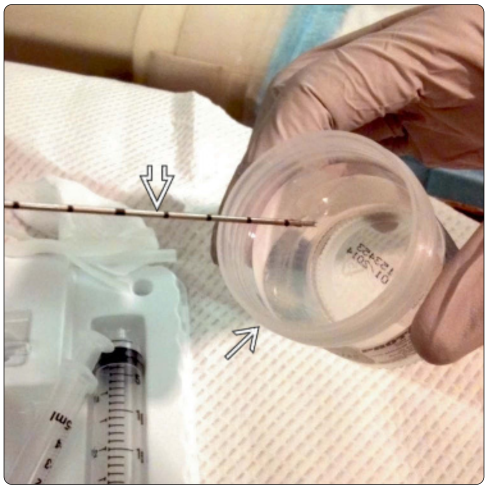


CT-Guided Lung Biopsy (Postbiopsy Imaging)

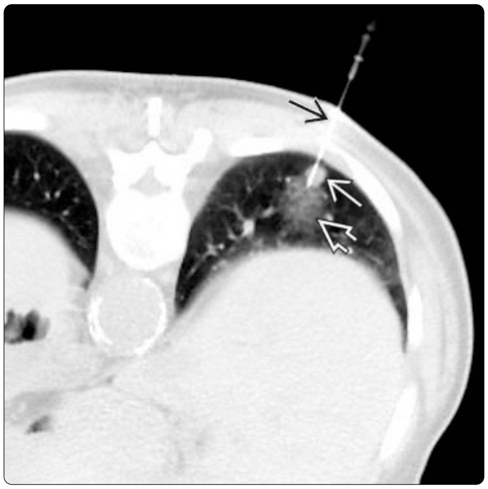


(Left) *The needle ↪ of a 20-gauge core biopsy gun ⇨ is being coaxially advanced into the introducer needle ➔ in preparation to obtain a core biopsy, in addition to the fine needle aspiration.* **(Right)** *CT image obtained after removing the introducer needle shows a small pneumothorax ➔ but no other obvious complication. The patient should be placed supine, as the patient's weight on the biopsy site reduces the risk of further enlargement of the pneumothorax.*

CT-Guided Lung Biopsy (Specimen Preparation)

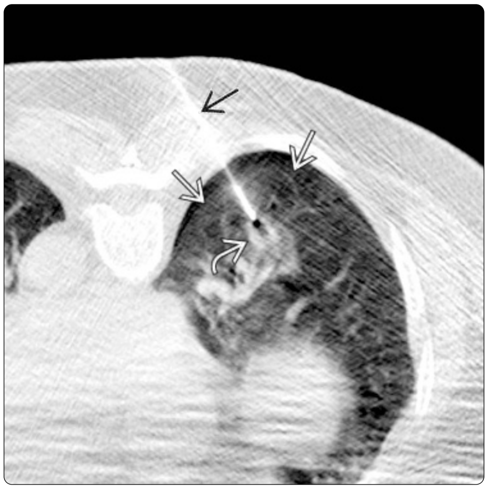


Inadvertent Advancement of Introducer Needle

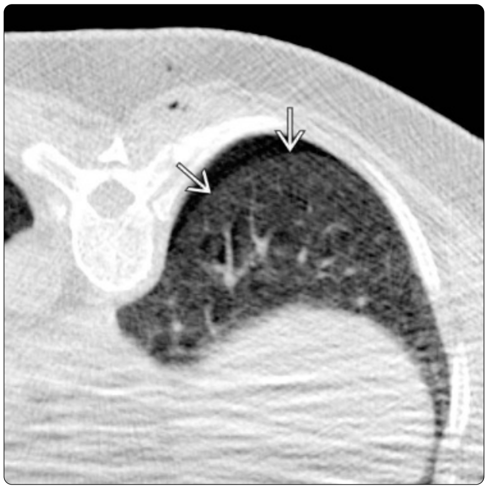


(Left) *After the core biopsy needle ⇨ is withdrawn from the introducer needle, the tissue core may be placed in a specimen jar ➔ containing either formalin or sterile saline. Specimen preparation should be performed per pathology department guidelines.* **(Right)** *In a different patient, biopsies produced tissue fragments, not expected cores. A postbiopsy CT shows the introducer needle → advance through the lesion ➔ during the procedure, resulting in biopsies of adjacent lung tissue ⇨, not mass.*

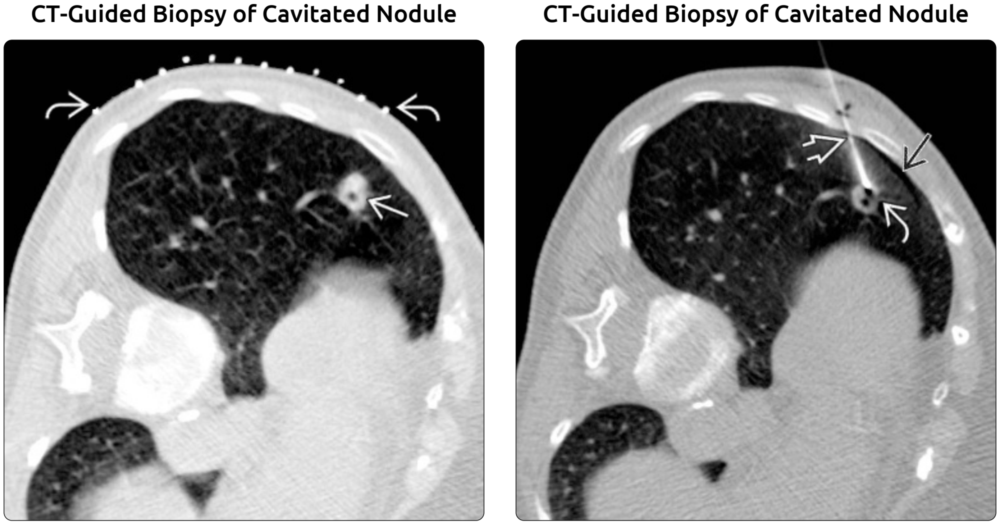
Lung Biopsy Complication (Pneumothorax)



Lung Biopsy Complication (Aspiration of Pneumothorax)



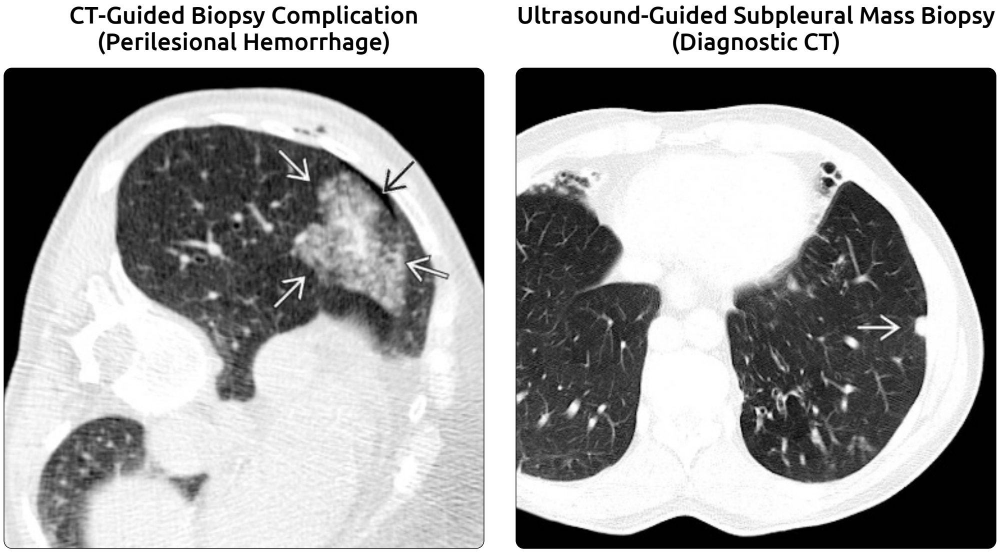
(Left) *An introducer needle → is positioned with the tip at the periphery of a pulmonary nodule ↪. A small pneumothorax ➔ is demonstrated.* **(Right)** *Image at a level caudal to the nodule shows the pneumothorax ➔ to better advantage. After completing the biopsy, the introducer needle was withdrawn while applying suction to an attached syringe, thus aspirating the pneumothorax. The postprocedure chest radiograph showed no pneumothorax.*



CT-Guided Biopsy of Cavitated Nodule

CT-Guided Biopsy of Cavitated Nodule

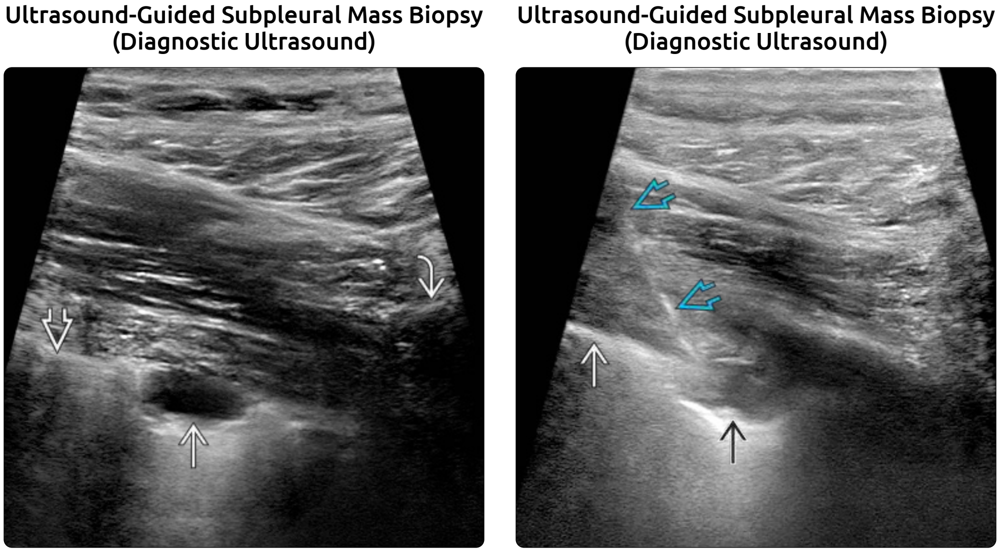
(Left) *A cavitated lung nodule ➡ is targeted, and an access path chosen with the aid of a radiopaque grid ➡ placed on the skin overlying the lesion. The patient is placed in the lateral decubitus position, as this provides the shortest route to the nodule.* **(Right)** *An introducer needle ➡ has been advanced into the peripheral aspect of the nodule ➡. It was elected to sample the periphery of the nodule in order to maximize diagnostic accuracy, as the tissue in the necrotic center may be nondiagnostic. A trace pneumothorax ⇨ is present.*



CT-Guided Biopsy Complication (Perilesional Hemorrhage)

Ultrasound-Guided Subpleural Mass Biopsy (Diagnostic CT)

(Left) *A geographic ground-glass opacity ➡ present after the biopsy, consistent with perilesional hemorrhage, is shown. Biopsy-associated perilesional hemorrhage such as this is not unusual and typically is self-limiting, although hemoptysis and coughing can result. Coughing could potentially worsen the pneumothorax ⇨.* **(Right)** *A 73-year-old man with prostate cancer was found to have a 1.2 cm subpleural nodule ➡. There was concern that respiratory-induced motion of the small target could lead to a false-negative result.*

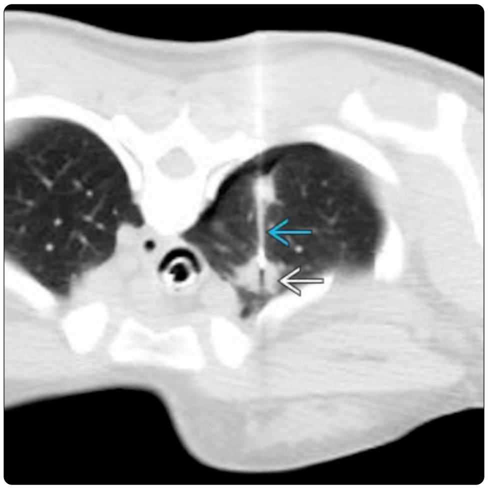


Ultrasound-Guided Subpleural Mass Biopsy (Diagnostic Ultrasound)

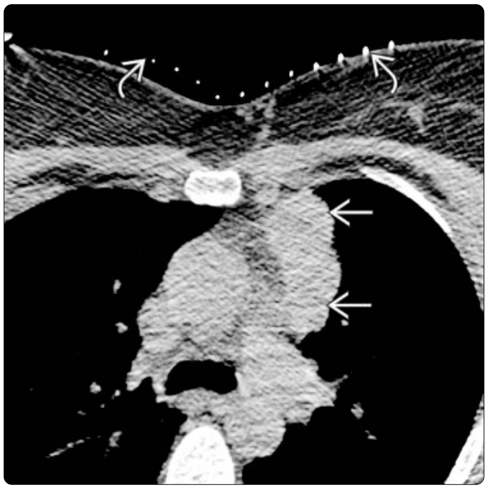
Ultrasound-Guided Subpleural Mass Biopsy (Diagnostic Ultrasound)

(Left) *A 9-Hz transducer clearly displays the lesion ➡ adherent to the pleural ➡, while air within the lung inhibits visualization of deeper structures. A shadow is cast from an adjacent rib ➡. The lesion moved from under the rib to the location shown during respirations.* **(Right)** *A 20-gauge biopsy gun ⇨ was advanced just outside of the pleura ➡. Real-time visualization of the moving lesion ⇨ during respirations enabled sufficient timing to core the lesion through the pleura. Coaxial technique was not utilized.*

Nondiagnostic Biopsy

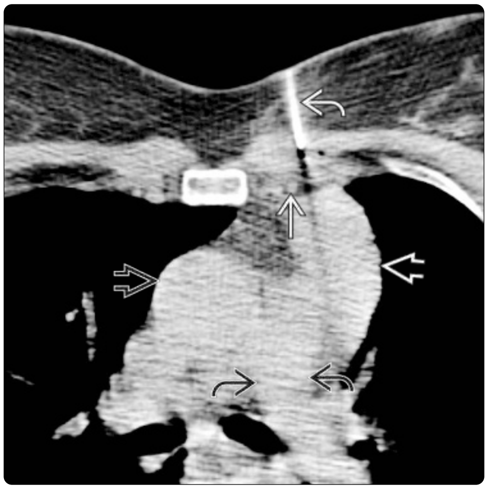


CT-Guided Mediastinal Mass Biopsy

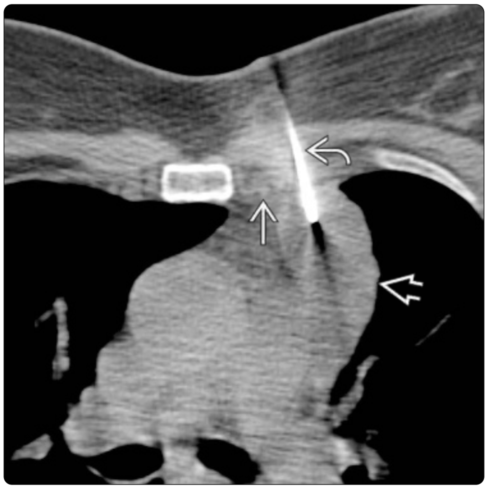


(Left) *This lesion ➡ biopsy was nondiagnostic despite ostensibly ideal needle → positioning. In fact, the needle trajectory was slightly craniocaudal at the top of the lesion, resulting in coring superior to the lesion during inspiration.* **(Right)** *In this preliminary image from a CT-guided biopsy of an anterior mediastinal mass ➡, the radiopaque localizing grid ↪ has been placed anteriorly on the skin overlying the abnormal mediastinum, so that a safe route for needle access can be chosen.*

CT-Guided Mediastinal Mass Biopsy

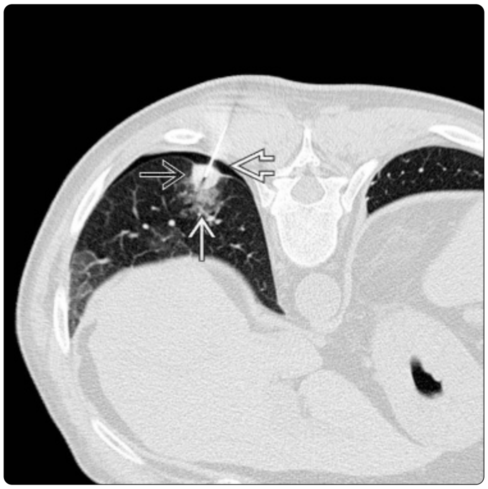


CT-Guided Mediastinal Mass Biopsy

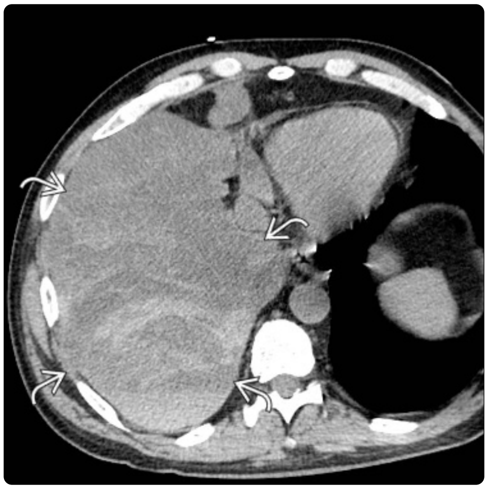


(Left) *An introducer needle ↪ is placed into the soft tissues superficial to the mediastinal mass ⇨. The internal mammary artery ➡, aorta ⇒, and pulmonary artery ↪ must be localized, and an appropriate needle trajectory chosen to avoid them.* **(Right)** *The introducer needle ↪ is advanced into the mass ⇨, avoiding the internal mammary vessels ➡. Always understand potentially intervening structures just superior and inferior to the planned biopsy and within the distal throw.*

Postbiopsy Hemothorax (Intraprocedural Imaging)



Postbiopsy Hemothorax (9-Day Follow-Up)



(Left) *Imaging during prone biopsy of a costophrenic mass ⇒ reveals slight intraparenchymal hemorrhage ➡ and a small pneumothorax ⇨. The pneumothorax resorbed on a subsequent 2-hour chest x-ray. The patient restarted systemic anticoagulation the following day.* **(Right)** *Nine days later, he returned to the emergency department short of breath. CT imaging revealed a massive hemothorax ↪, which was evacuated intraoperatively. No active bleeding was ever discovered.*

Transforaminal Nerve Blocks

KEY FACTS

TERMINOLOGY

- **Nerve block**: Selective anesthesia of spinal nerve root at level of neural foramen

PREPROCEDURE

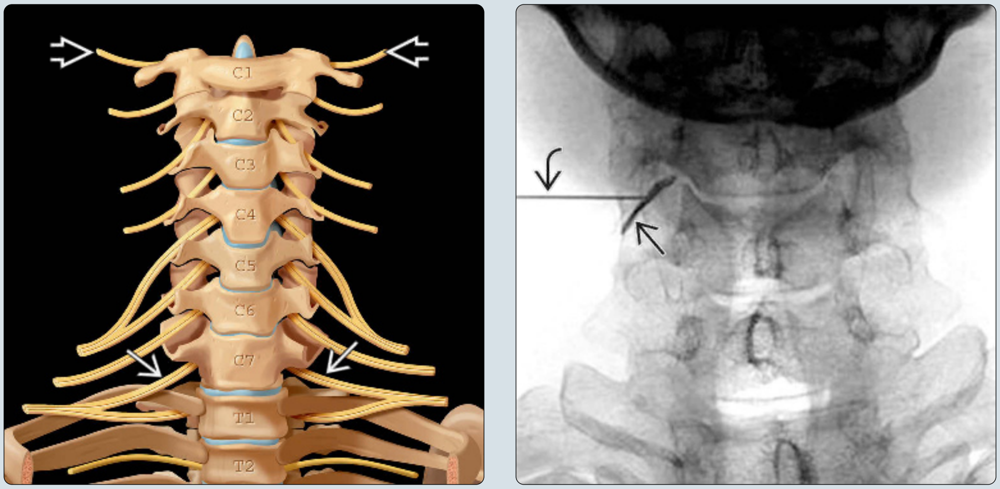
- Indications
  - Radiculopathy corresponding to spinal nerve root
  - Degenerative disc or facet disease
- Preprocedure imaging
  - Determination of causative lesion
  - Evaluation of multi- vs. single-level disease

PROCEDURE

- **Cervical**
  - Position: Supine with lateral approach
- **Thoracic/lumbar**
  - Position: Prone with dorsolateral approach
- Confirm intraforaminal needle tip placement
  - Beneath lateral pedicle cortex (frontal view)
- Document any change in patient's pain and concordant/discordant pain reproduction during injection

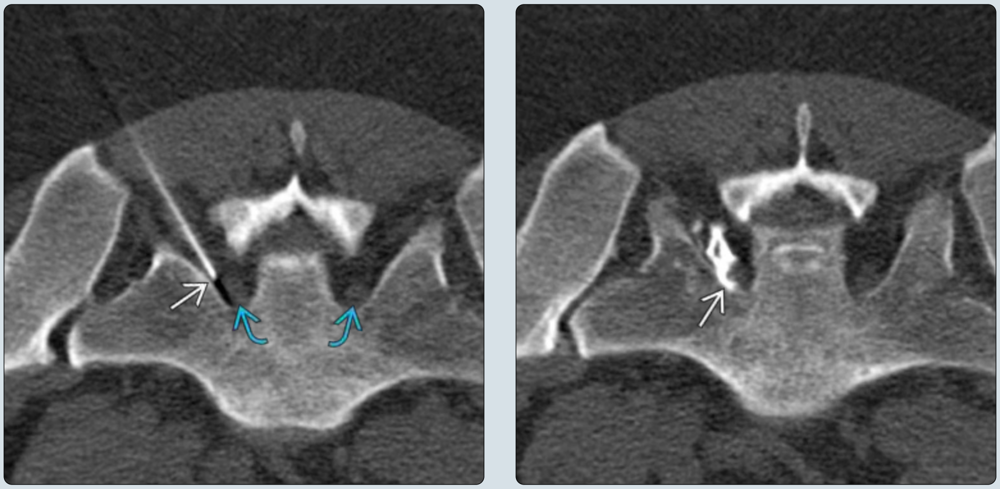
POST PROCEDURE

- Expectations
  - Significant improvement in pain, corresponding to nerve root(s) injected
  - 48-72 hours for corticosteroid to take full effect
  - Pain may worsen in interval between anesthetic wearing off and corticosteroid taking effect
- Problems
  - Failure to relieve pain
    - Injection not localized to neural foramen
    - Incorrect level injected; count levels carefully
  - Vasovagal reaction
- Most feared complications
  - Nerve root injury
  - Vascular or spinal cord injury
  - Pneumothorax


Nerve Roots and Cervical Vertebra (Coronal Graphic)

C6 Nerve Root (Contrast Highlight)

(Left) *Coronal graphic shows the relationship of the exiting nerve roots to the cervical vertebrae. The C1 nerve root ➡ exits between the occipital bone and C1 while the C8 nerve root ➡ exits via the C7-T1 neural foramen.* **(Right)** *Posteroanterior fluoroscopic spot radiograph following needle ⇨ placement for a right C6 contrast injection and selective nerve root block (SNRB) shows contrast tracking along the exiting right C6 nerve root ⇨.*


S1 Nerve Root Block (Needle Positioning)

S1 Nerve Root Block (Nerve Root Sleeve)

(Left) *Axial CT following needle placement for a right S1 nerve root block shows the needle tip ➡ adjacent to but outside of the nerve roots ⇨. An advantage of CT guidance is direct visualization of the nerve roots.* **(Right)** *Axial CT after injection of steroid and anesthetic mixed with contrast shows injectate outlining the nerve root sleeve ➡.*

TERMINOLOGY

Definitions

- **Nerve block**: Selective anesthesia of spinal nerve root at level of neural foramen
  - a.k.a. selective nerve root block

PREPROCEDURE

Indications

- Radiculopathy corresponding to spinal nerve root
  - Degenerative disc or facet disease
  - Extrinsic compression from neoplasm/other cause
- Pain after vertebroplasty/kyphoplasty

Contraindications

- Local or systemic infection
- Coagulopathy
- Allergy to injectate
- Recent vaccination (live microorganism preparation)
- Relative contraindications: Iodinated contrast allergy, pregnancy (teratogenic effects of radiation)

Preprocedure Imaging

- Radiography
  - Evaluate potential degenerative disc or facet disease narrowing neural foramina
    - Endplate sclerosis, disc space narrowing
    - Osteophytosis/bony eburnation narrowing foramina
- CT
  - Provides more detailed visualization of bony causes of neural foraminal narrowing
- CT myelography
  - Directly visualizes spinal nerve roots
  - Less artifacts compared with magnetic resonance in patients with spinal hardware
- MR
  - Directly visualizes spinal nerve roots
  - Provides more detailed visualization of lesions compressing nerve roots: Disc protrusions, facet joint effusion, synovial cysts, soft tissue masses

Getting Started

- Things to check
  - Imaging: Causative lesion, multi- vs. single level
  - Coagulation parameters as indicated
  - Informed consent
- Medications
  - Corticosteroid
  - Long-acting anesthetic (e.g., 0.5% bupivacaine)
  - Short-acting local anesthetic (e.g., 1% lidocaine)
  - Iodinated contrast (myelography safe)
- Equipment list
  - Sterile preparatory and draping materials
  - 10 mL syringe; 25-g needle for local anesthetic
  - 10 mL syringe and tubing for contrast
  - 3 mL syringe for injectate
  - 22-g spinal needle (or other preferred needle) for access/injection

PROCEDURE

Patient Position/Location

- Best procedure approach
  - **Cervical**
    - Supine position, lateral approach
      - Must have true lateral fluoroscopic view of cervical vertebrae, align vertebral and facet margins
      - Visualizing mid to lower cervical spine on lateral fluoroscopy may be difficult due to shoulder position, maneuvers exist to "pull" arms down without patient effort to improve visualization
      - Target superior articular process of same number vertebra as nerve being injected (nerve comes out at level above pedicle in cervical spine)
  - **Thoracic**
    - Prone position
      - Carefully discern pleural reflections
      - Consider placing gentle curve in distal 1/3 of needle to aid in keeping needle tip medial to pleura/facilitate directing needle into foramen
  - **Lumbar**
    - Prone position
      - Frontal view: Approach from lateral at ~ 45° angle
      - Ipsilateral oblique view: Follow radiograph beam with needle "down the barrel" view

Equipment Preparation

- Draw 10 mL of 1% lidocaine
- Draw 5-10 mL of iodinated contrast (myelography safe)
- Draw injectate [e.g., 80 mg methylprednisolone and 0.5% bupivacaine (1-2 mL)], leaving room in syringe to allow mixing immediately prior to injection

Procedure Steps

- **General**
  - Observe universal protocol ("time out")
  - Mark skin entry site, then ensure correct spinal level
  - Sterilely prepare and drape skin
  - Administer local anesthetic
  - Place procedure needle deep enough to anchor in subcutaneous tissue
  - Verify needle trajectory to target
    - Use frontal and lateral projections with fluoroscopy, biopsy mode images with CT
  - Advance needle toward target
    - Use intermittent imaging until target reached
    - Be prepared for patient to jump &/or vocalize if nerve root contacted
- **Cervical**
  - Target anterior aspect of superior articular facet of same-numbered vertebra as nerve to be injected
  - Advance needle toward target
  - Confirm osseous contact at anterior aspect of superior articular facet
  - Carefully deflect needle anteriorly and advance slowly into neural foramen posteriorly to avoid vertebral artery
- **Thoracic**
  - Be certain to count entire thoracic spine
  - Mark skin, allowing for needle trajectory that is medial to pleural margin

  - Carefully advance needle using intermittent imaging guidance
  - If bone encountered, articular facet most likely culprit
    - Use oblique imaging to evaluate needle tip placement
    - "Walk" needle anteriorly until able to advance into foramen
- **Lumbar**
  - Frontal view: Skin entry ~ 6-8 cm lateral to neural foramen
  - Oblique view (~ 45° toward involved side)
    - Target below pedicle/"eye" of "Scotty dog," then guide needle along axis of radiograph beam
  - Carefully advance needle
  - If bone encountered, articular facet most likely culprit
    - Use oblique imaging to evaluate needle tip placement
    - Carefully "walk" needle anteriorly until able to advance
- **All levels**
  - Confirm intraforaminal needle tip placement
    - Beneath lateral pedicle cortex on frontal view
    - Within foramen on lateral view
  - Remove stylette and observe hub for blood
  - Attach contrast tubing; gently aspirate to confirm extravascular needle tip placement
  - Slowly inject contrast
    - Should see contrast tracking along nerve root away from foramen; suggests good location to deliver injectate
    - Contrast spreading medially, beneath pedicle, indicates transforaminal epidural injection; injectate may be delivered, but epidural injection should be reported
    - Should not see vascular enhancement, contrast pooling, or feathering within skeletal muscle
  - Document needle tip placement with image(s)
  - Attach injectate syringe and inject slowly
    - Mix injectate immediately prior to injecting as steroid and anesthetic will separate
  - If unable to inject due to contrast clogging needle, place portion of injectate in 1 mL syringe
    - High-pressure injection will usually overcome barrier to injection
    - Warn patient that injection may be quite painful
  - Note whether concordant pain reproduced during injection
    - Note pain quality/intensity before/during/after injection
  - Remove needle and obtain hemostasis
  - Clean skin and apply bandage
  - Sit patient up and assess strength
  - Assist patient from table
    - Should always involve 2 assistants in case of weakness/syncope

Findings and Reporting

- Change in patient's pain
  - Document intensity before, during and after injection
  - Document concordant/discordant pain reproduction during injection
- Level(s)/side injected
- Components of injectate: Anesthetic ± steroid
- Whether epidural steroid injection (ESI) was also noted during injection (transforaminal ESI)
- Any complications

POST PROCEDURE

Things to Do

- Establish clinical follow-up
- Remind patient to keep pain diary until next clinic visit

Things to Avoid

- Patient should not submerge injection site in water for ~ 48 hours

OUTCOMES

Problems

- Failure to relieve pain
  - Technical failure
    - Injection not properly localized to nerve root sleeve in neural foramen
    - Wrong level injected
  - Clinical failure
    - Wrong level chosen for injection
    - Multifactorial pain
- Vasovagal reaction

Complications

- Most feared complication(s)
  - Vascular injury
    - Cerebral or spinal infarction
    - Intraspinal hematoma
  - Spinal cord injury
    - Direct puncture or compression by hematoma
    - Meningitis
  - Pneumothorax
- Delayed complication(s)
  - Postdural puncture headache
- Other complications
  - Nerve root injury
  - Bleeding
  - Infection

Expected Outcomes

- Significant improvement in pain, corresponding to nerve root(s) injected
  - May take 48-72 hours for corticosteroid to take full effect
  - Pain may worsen in interval between anesthetic wearing off and corticosteroid taking effect

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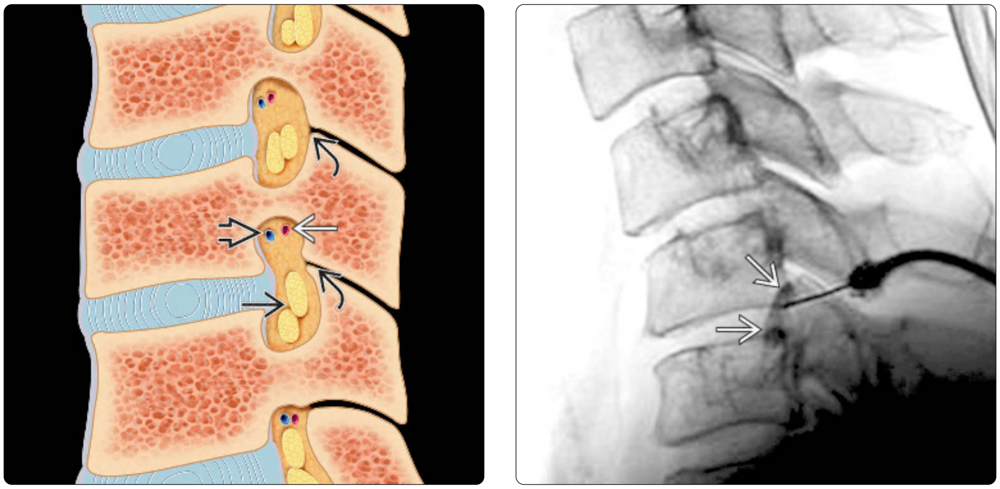
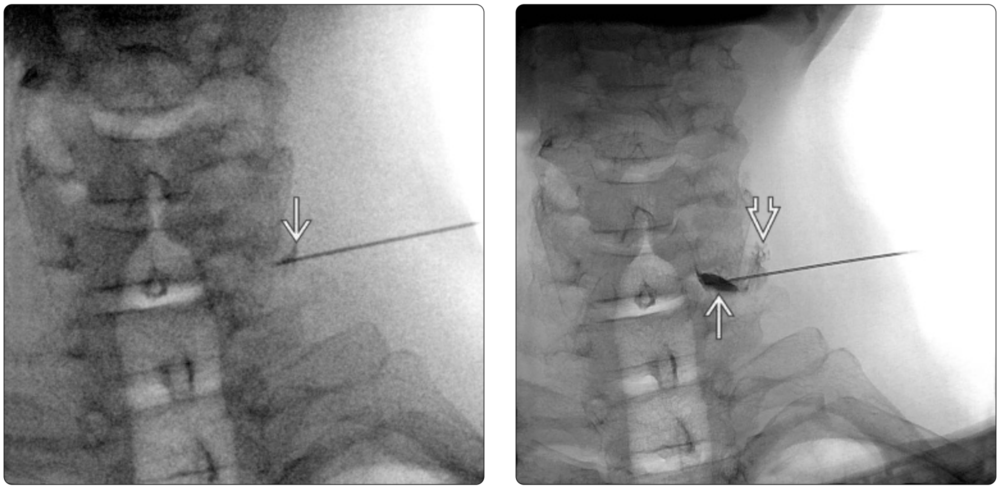


Cervical Nerve Roots (Parasagittal)

Cervical Nerve Roots: Needle Placement (Lateral View)

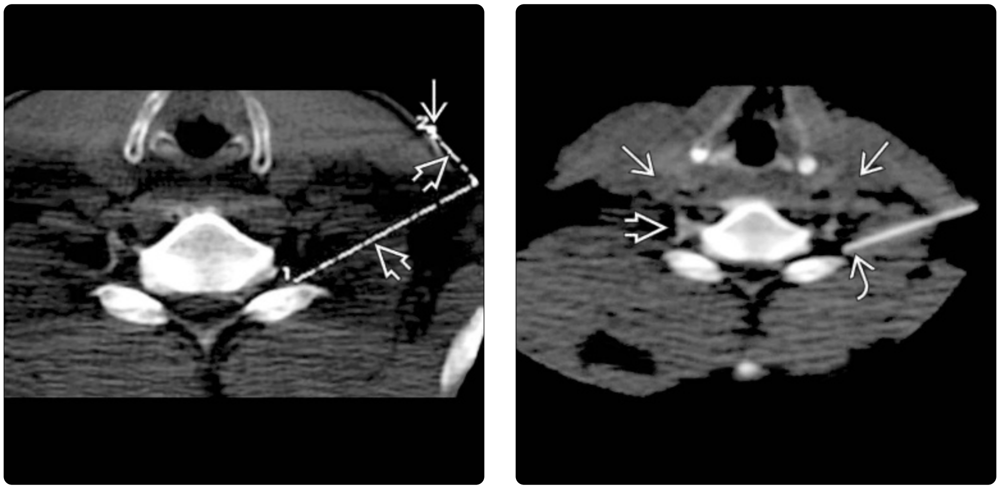
(Left) *Parasagittal graphic shows the anatomic relationship of the cervical nerve roots ⇨ (surrounded by adipose tissue) to the accompanying artery ➡ and vein ⇨ and superior articular facet ⤻. This facet is the target for a cervical SNRB.* **(Right)** *Lateral fluoroscopic spot radiograph obtained after anterior needle deflection off of the superior articular facet, followed by contrast injection, shows that the contrast tracks along the C6 nerve root ➡.*



Cervical Left C7 SNRB (Extraforaminal)

Cervical Left C7 SNRB (Foraminal)

(Left) *Frontal fluoroscopic spot radiograph after contrast injection documents contrast ➡ outside of the neural foramen. With a successful needle tip placement, contrast should opacify the neural foramen &/or extend obliquely away it.* **(Right)** *AP spot radiograph in the same patient after needle repositioning shows that the contrast injection is localized to the left neural foramen ➡, the desired location. Note the residual contrast from the earlier extraforaminal injection ➡.*

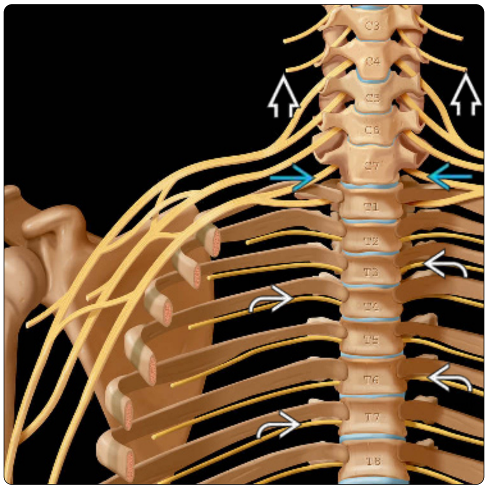


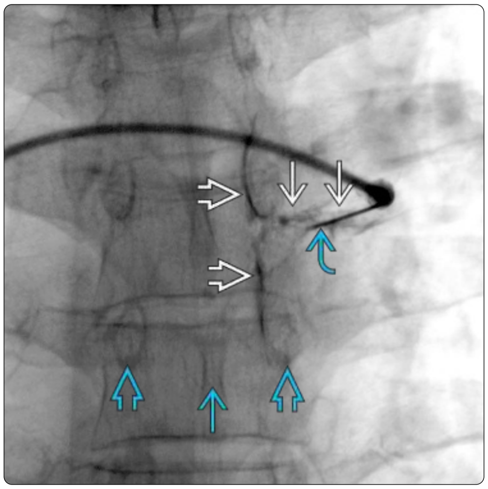
Cervical CT Guidance (Trajectory Planning)

Cervical CT Guidance (Needle Placement)

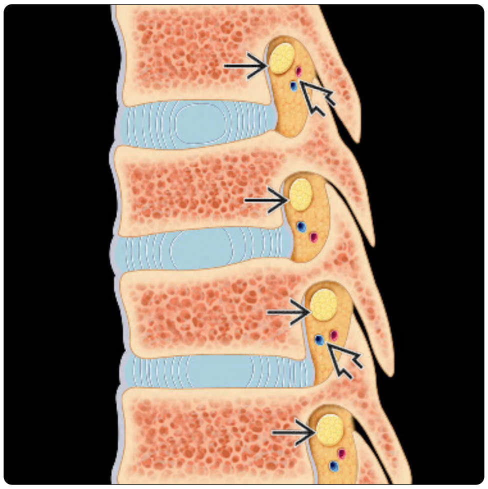
(Left) *Axial CT obtained for localization of a cervical neural foramen shows the measurement lines ➡ used to determine approach. These lines extend from a radiopaque marker ➡ on the skin.* **(Right)** *Axial CT in the same patient shows the needle tip ➡ positioned along the lateral margin of the neural foramen. The ventrolateral approach is essential for avoiding critical vascular structures. Note the carotid sheath ➡ and the expected location of the vertebral artery in the transverse foramen ➡.*

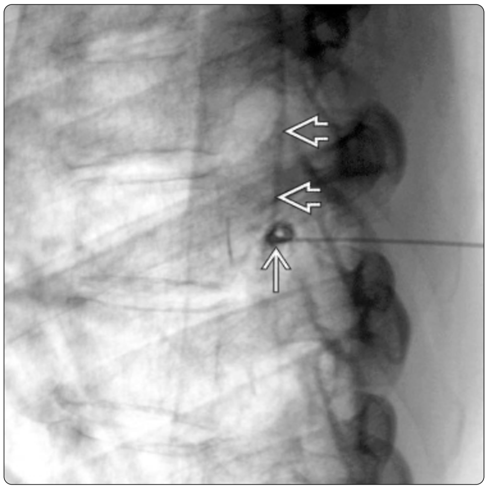
(Left) *Coronal graphic depicts the cervical nerve roots ⇨ exiting above their corresponding pedicle while the thoracic (and lumbar) nerve roots ↪ exit below the corresponding pedicle. Note that the C8 nerve roots → exit between C7 and T1.* **(Right)** *Fluoroscopic spot radiograph after needle ↪ placement shows contrast → within a right thoracic neural foramen. Note the linear extension along the exiting nerve root and medial extension into the epidural space ⇨. Also note the pedicles ⇨ and spinous process →.*


Thoracic Nerve Roots (Coronal)

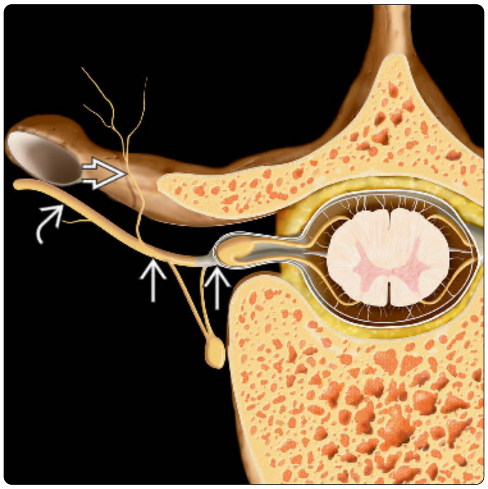

Thoracic Coronal Foraminal Injection (Transforaminal Epidural Steroid Injection)

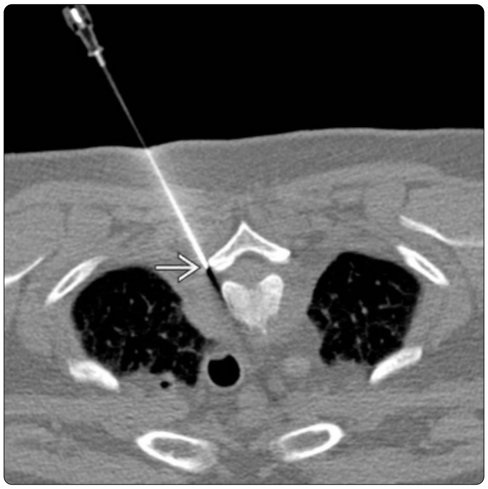
(Left) *The graphic depicts the thoracic spinal nerves → exiting neural foramina superiorly in contradistinction to the cervical nerve roots. This relationship is also maintained in the lumbar region. Note that the artery and vein are located inferiorly ⇨ relative to the nerve.* **(Right)** *Lateral fluoroscopic spot radiograph in the same patient shows contrast within the neural foramen → and extending into the epidural space ⇨. A transforaminal epidural steroid injection should be reported in this case.*


Thoracic Neural Foramina (Parasagittal)

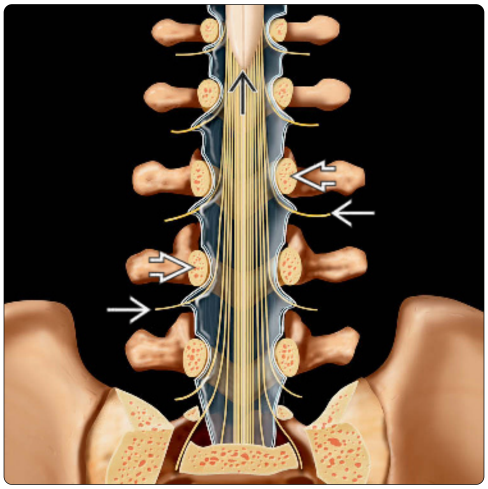

Thoracic Sagittal Foraminal Injection (Transforaminal Epidural Steroid Injection)

(Left) *Axial graphic shows a lower thoracic vertebral segment with a typical thoracic spinal nerve → giving rise to ventral ↪ and dorsal ⇨ primary rami.* **(Right)** *Axial NECT shows needle tip → placed at the posterior margin of the neural foramen. Note the dramatically improved visualization of the lungs and other soft tissue structures with CT-guided thoracic nerve block procedures.*

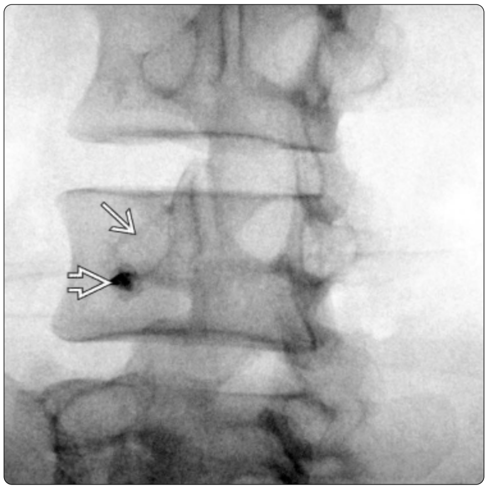

Thoracic Spinal Nerve and Rami (Axial)


Thoracic Axial Needle Placement (CT)

Lumbar Nerve Roots (Coronal)

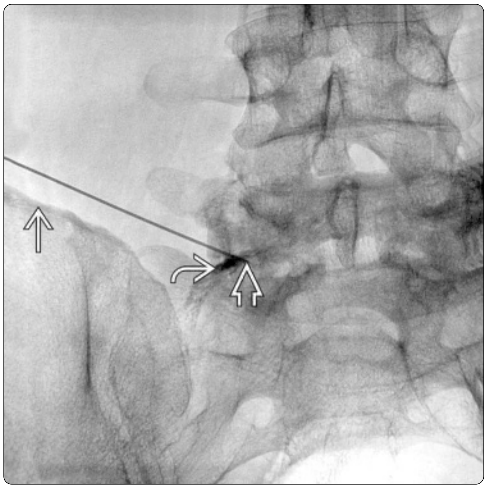


Lumbar Needle Placement (Oblique View)

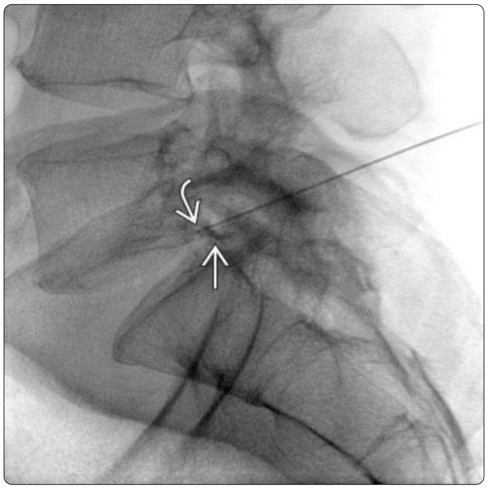


(Left) *Coronal graphic shows the distal thoracic spinal cord ending in the conus medullaris →. The lumbar nerve roots ➔ exit the thecal sac beneath the pedicles ⇨ of the vertebral segment of the same number, just as in the thoracic spine.* **(Right)** *Oblique "Scotty dog" fluoroscopic imaging of the lumbar spine permits targeting the neural foramen beneath the pedicle/"eye" ➔ while advancing the needle directly along the imaging beam ⇨ "down the barrel." Intermittent lateral imaging is essential to determine the appropriate needle depth.*

Lumbar Needle Placement (AP View)

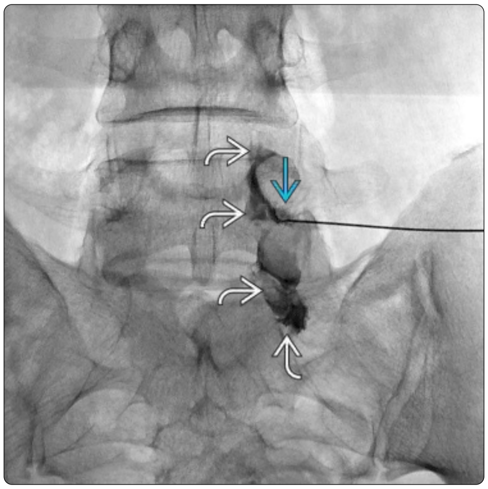


Lumbar Needle Placement (Lateral View)

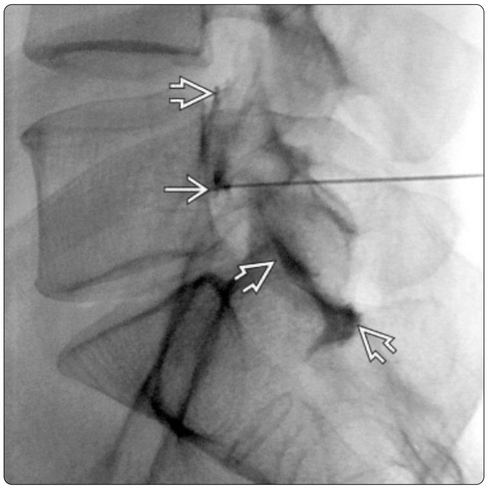


(Left) *AP fluoroscopic spot radiograph obtained after needle ⇨ placement, followed by contrast injection, shows contrast tracking along the left L5 nerve root ↪. Note the angled trajectory of the needle that was used to avoid the iliac crest ➔.* **(Right)** *Lateral radiographic view shows the needle depth ↪ to be satisfactory in the anterior/inferior L5 neural foramen. In comparing the AP and lateral views, contrast is flowing away from the needle tip within the neural foramen and along the exiting nerve root ➔.*

Lumbar Intraforaminal and Epidural Injection (AP View)



Lumbar Intraforaminal and Epidural Injection (Lateral View)



(Left) *AP fluoroscopic spot radiograph shows that the needle tip lies deep within the L5 neural foramen, beneath the central aspect of the pedicle →. Contrast injected within the neural foramen extends into the epidural space from the L5-S1 levels ↪.* **(Right)** *Lateral fluoroscopic spot radiograph in the same patient confirms that the needle tip ➔ lies deep within the neural foramen. Contrast is within the epidural space ⇨ from the L5-S1 levels. Epidural delivery of injectate is acceptable.*

Facet Blocks

KEY FACTS

TERMINOLOGY

- **Facet joint block**: Anesthetic ± corticosteroid injection into cervical, thoracic, or lumbar facet joint
  - Diagnostic/therapeutic study to evaluate pain referable to facet joint

PREPROCEDURE

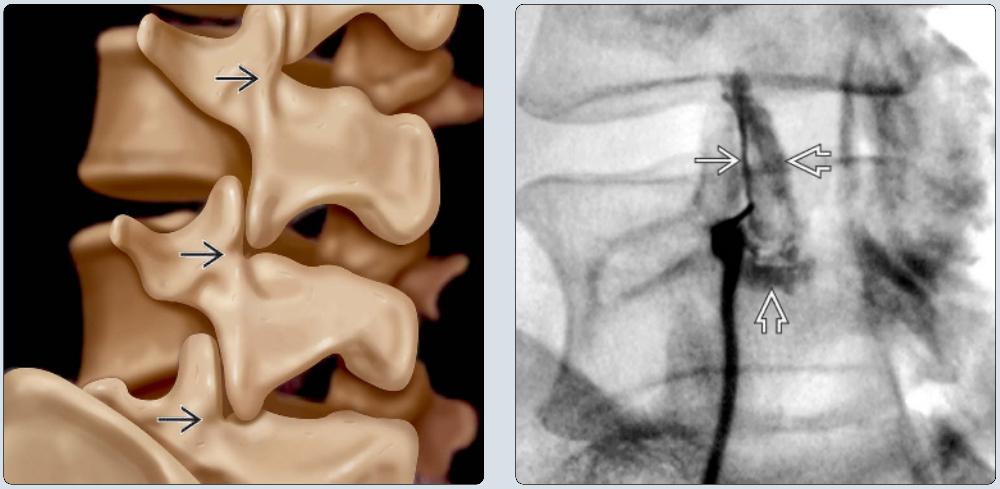
- Indications
  - Chronic or acute on chronic facet osteoarthritis
  - Posttraumatic osteoarthritis
  - Symptomatic synovial cyst

PROCEDURE

- Supine position
  - Occiput/C1 level: Lateral approach
  - C2/C3-C7/T1: Lateral approach
- Prone position
  - C1/C2: Posterior approach
  - T2/3-L5/S1: Posterolateral approach
- May require CT guidance
  - Multiplanar reformats may be helpful
- Needle placement easiest in lower 1/3 of joint space
- Injection of local anesthetic for diagnostic or steroid for therapeutic purposes
- Symptomatic synovial cyst may be ruptured with same technique

POST PROCEDURE

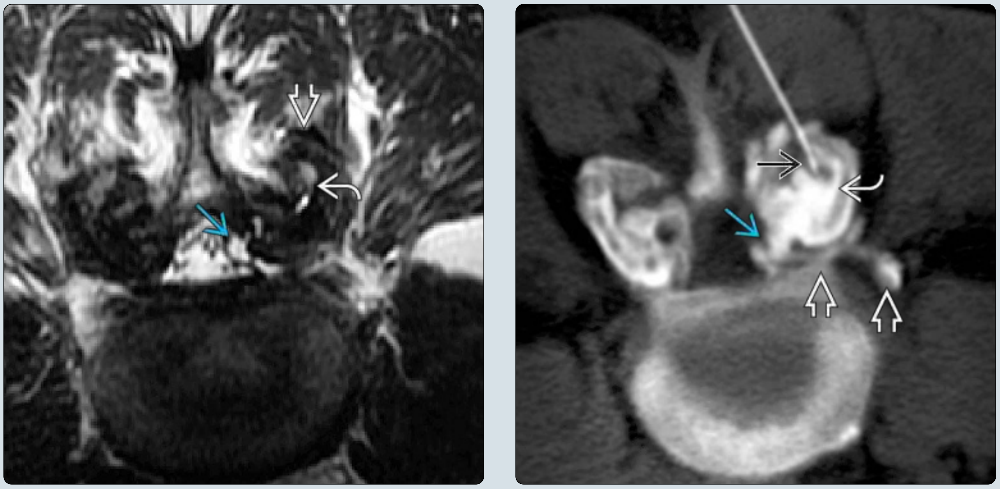
- Expectations
  - Reproduction of pain with injection
  - Improvement in pain following injection
- Problems
  - Failure to improve/alleviate clinical symptoms
  - Vasovagal reaction
- Most feared complications
  - Vascular &/or spinal cord injury
  - Pneumothorax



Facet Anatomy

Facet Injection

(Left) *An oblique graphic shows "Scotty dog" anatomy of the lumbar spine. At the superior articular facet and transverse process junction* → *, the medial branch of the primary dorsal ramus is located within a small osseous groove.* **(Right)** *A fluoroscopic spot radiograph obtained during a lumbar facet joint injection shows contrast* ⇨ *around the joint; note the linear craniocaudal extension of contrast* ⇨ *, which is characteristic of an intraarticular injection.*



Symptomatic Synovial Cyst (T2 MR)

Rupture of Synovial Cyst (CT)

(Left) *A lumbar synovial cyst* → *encroaches on the spinal canal and left lateral recess. Bony overgrowth* ⇨ *and irregularity of the facet joint line* ⇨ *are evident.* **(Right)** *Using CT-guidance, saline, anesthetic, and contrast were injected into the facet joint of the same patient. The needle tip* → *is in the joint. Contrast in the joint line* ⇨ *extends into the synovial cyst* → *and the epidural/perineural space* ⇨ *. Extension of contrast outside the joint indicates successful cyst rupture.*

TERMINOLOGY

Definitions

- **Facet joint block**: Anesthetic ± corticosteroid injection into cervical, thoracic, or lumbar facet joint
- Study to evaluate and treat pain referable to facet joint

PREPROCEDURE

Indications

- Chronic facet osteoarthritis
- Acute exacerbation of chronic facet osteoarthritis
- Posttraumatic osteoarthritis
- Symptomatic synovial cyst

Contraindications

- Local or systemic infection
- Allergy to injectate
- Relative: Pregnancy; allergy to iodinated contrast

Preprocedure Imaging

- Radiography
  - Facet joint alignment
  - Advanced facet joint degenerative changes
  - Joint space narrowing
  - Intraarticular gas (vacuum phenomenon)
- CT
  - More sensitive than radiography for osteoarthritis
  - Foraminal stenosis secondary to facet osteophytes
  - Joint space narrowing; sclerotic changes of facets
  - Vacuum phenomenon
  - Contrast commonly shows inflammatory soft tissue changes around facet joints
- MR
  - Synovial thickening
  - Inflammatory changes surrounding facet joints
  - Osteophytic narrowing of adjacent neural foramina
  - Facet joint effusion
  - Synovial cyst

Getting Started

- Things to check
  - Previous diagnostic imaging
    - Assess bone overgrowth: Plan access to joint
    - Correlate imaging abnormality with symptoms
  - Coagulation parameters: Per institutional guidelines
    - International normalized ratio: For patients receiving warfarin
    - Platelet count: Not routinely recommended
  - Signs or symptoms of infection/inflammation
    - Elevated body temperature, white blood cell count
    - C-reactive protein, erythrocyte sedimentation rate
  - Previous surgery &/or pain injections
    - When performed
    - What type of surgery &/or injection
    - Efficacy of prior intervention
  - Physical examination
    - Assess muscle strength
    - Evaluate site of pain and aggravating factors (e.g., flexion/extension)
  - Informed procedural consent obtained
- Medications
  - Local anesthetic (e.g., 1% lidocaine)
  - Long-acting anesthetic (e.g., bupivacaine)
  - Corticosteroid (if therapeutic injection is desired)
  - Iodinated contrast (that is safe for intrathecal injection)
- Equipment list
  - Radiopaque skin marker
  - Sterile skin preparatory and draping materials
  - Injection needle (e.g., 22-gauge spinal needle)
  - 1.5" 25-gauge needle; 5-mL syringe
    - For local anesthetic
  - 5- to 10-mL syringe; extension tubing
    - For iodinated contrast
  - 3-mL syringe for injectate

PROCEDURE

Patient Position/Location

- Best procedure approach
  - C1/C2
    - Patient position: Prone
    - Approach: Posterior
  - Occiput/C1, C2/C3-C7/T1
    - Patient position: Supine
    - Optimal approach: Lateral
    - Alternate approach
      - ☐ Decubitus: Affected side up
      - ☐ Place cushion beneath head, allowing mild tilting away from side to be injected (opens joint space)
  - T2/T3-L5/S1
    - Patient position: Prone
    - Approach: Posterior
      - ☐ Oblique imaging toward side of joint to be injected to "open joint" fluoroscopically
      - ☐ In thoracic region, attention to medial pleural reflections to avoid pleural puncture/pneumothorax
      - ☐ May require CT guidance to achieve intraarticular needle placement

Equipment Preparation

- Draw 5 mL of local anesthetic; attach 25-gauge needle
- Draw 5-10 mL of myelography-safe iodinated contrast and attach and preload extension tubing
  - Purge air from tubing and syringe in case of inadvertent arterial injection
- Draw 0.5-1.0 mL of long-acting anesthetic and 0.5-1.0 mL of corticosteroid (if desired)

Procedure Steps

- **Facet joint block**
  - Procedure "time out"
    - Verify correct patient, correct level(s), side(s) to be injected, correct procedure, all equipment available
  - Carefully mark correct level(s) for intervention
  - Sterilely prepare and drape skin
  - Administer local anesthetic
  - Insert injection needle into subcutaneous tissue, assess trajectory with fluoroscopy or CT
  - Slowly advance needle under intermittent imaging guidance until needle is in joint space

        - Avoid needle entry into spinal canal
    - Often lower 1/3 of joint space most amenable to needle placement
    - If bone encountered prior to entering joint space, stop and assess needle tip position
        - Tip may be against superior or inferior articular facet
        - "Walk" needle gently into joint space
            - Avoid bending needle
            - Often requires initial withdrawal of needle 2-3 cm to redirect needle tip
            - Use bevel of needle tip to help "steer" needle tip away from side of bevel
    - Entry into joint space often accompanied by "pop"
    - Remove stylette
        - Ensure no blood return to confirm extravascular needle placement
    - Attach preloaded contrast syringe and extension tubing
        - Aspirate gently to confirm extravascular
    - Inject only enough contrast to confirm intraarticular needle tip placement
        - Acquire image to document satisfactory position
    - Attach injectate syringe
        - Remix injectate immediately prior to injection if corticosteroid used
        - Begin injection as soon as possible to avoid contrast "clogging" of injection needle
            - If this occurs, use 1-mL syringe with injectate to clear contrast from needle
    - Inject slowly as patient will likely experience significant reproduction of pain
        - Note patient's pain before, during, and immediately following injection
            - Procedural pain concordant or discordant with baseline pain
            - Pain intensity and character
- **Synovial cyst therapeutic rupture**
    - Same steps as facet joint block
        - Goal to overpressurize cyst through joint capsule to disrupt it
        - Alternate approach: Interlaminar cyst puncture
            - CT guidance suggested for alternate approach
    - Patient will often feel cyst rupture
        - May require significant injection pressure
        - Can be quite painful for patient
    - Sudden spread of contrast into epidural space is seen with cyst rupture
- Remove needle and obtain hemostasis
- Cleanse skin with hydrogen peroxide; apply bandage
- Reassess patient's pain; signs &/or symptoms to suggest complication
- Assist patient from procedure table when ready

Findings and Reporting

- Assessment of patient's pain
    - Concordant or discordant
        - Separate procedural from baseline pain
    - Character and intensity (scale of 1-10)
        - Before, during, and after injection
- Document level(s) of injection
- Injectate used
- Complications

POST PROCEDURE

Things to Do

- Establish clinical follow-up
- Remind patient to maintain pain diary between clinic visits to establish effectiveness of injection

Things to Avoid

- Submersion of needle entry site for 24-48 hours

OUTCOMES

Problems

- Failure to improve/alleviate clinical symptoms
    - Technical failure
        - Incorrect level injected
            - Multiple level injections may be necessary
        - Extraarticular injection
    - Clinical failure
        - Incorrect level determined by clinical examination
        - Facet joint not source of patient's pain
- Vasovagal reaction

Complications

- Most feared complication(s)
    - Vascular injury or intravascular injection
        - Cerebral or spinal cord ischemia/stroke
    - Spinal cord injury
        - Direct puncture
        - Compression from hematoma
    - Pneumothorax
- Delayed complication(s)
    - Infection: Meningitis, osteomyelitis/septic facet arthritis, local skin/subcutaneous infection
- Other complications
    - Bleeding
    - Nerve root injury

Expected Outcome

- High percentage of technical success
    - Reproduction of pain during injection suggests that injected facet is symptom generator
- Improvement in pain following injection
    - Degree and duration of relief varies among patients

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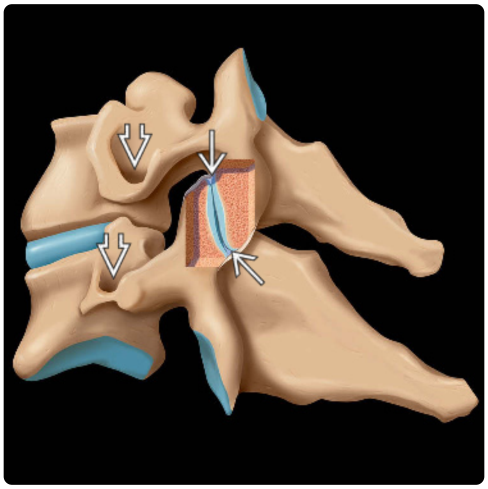
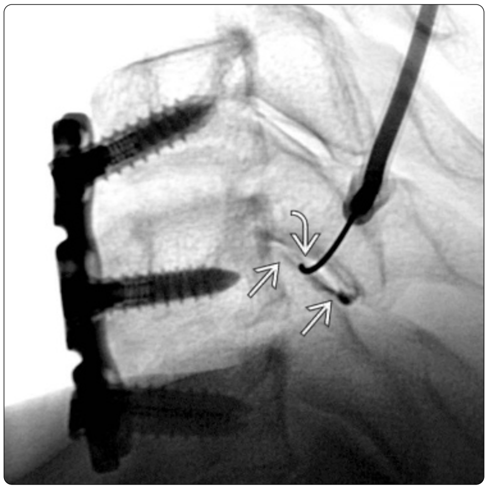
2. Iannuccilli JD et al: Interventional spine procedures for management of chronic low back pain-a primer. Semin Intervent Radiol. 30(3):307-17, 2013
3. Weininger M et al: Accuracy of CT guidance of lumbar facet joint block. AJR Am J Roentgenol. 200(3):673-6, 2013
4. Fotiadou A et al: Management of low back pain with facet joint injections and nerve root blocks under computed tomography guidance. a prospective study. Skeletal Radiol. 41(9):1081-5, 2012
5. Manchikanti L et al: A critical review of the American Pain Society clinical practice guidelines for interventional techniques: part 1. Diagnostic interventions. Pain Physician. 13(3):E141-74, 2010
6. Manchikanti L et al: A critical review of the American Pain Society Clinical practice guidelines for interventional techniques: part 2. Therapeutic interventions. Pain Physician. 13(4):E215-64, 2010

Cervical Normal Facet Joint Anatomy

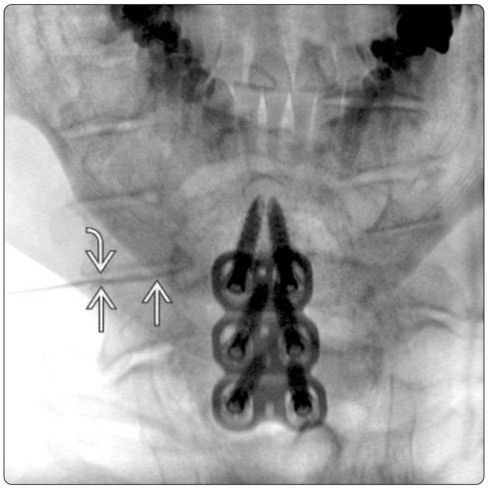


Cervical C3/C4 Facet Injection

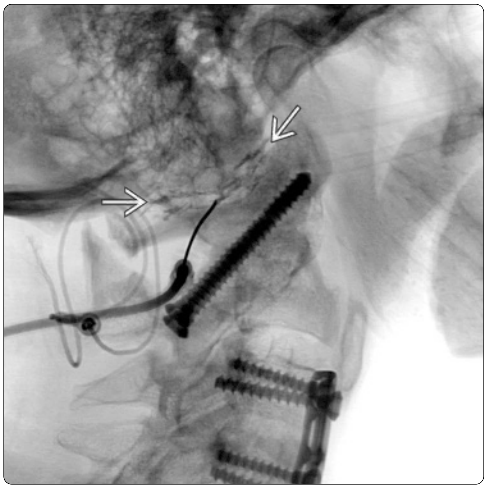


(Left) *Sagittal graphic shows the steep oblique orientation of the subaxial cervical facet joints →, which often precludes percutaneous access from a posterior approach. Note the transverse foramina ⇨, which transmit the vertebral artery.* **(Right)** *Lateral radiograph shows that the tip of a needle has been positioned within the facet joint ↪, entering from a lateral approach. Note that there is contrast spreading throughout the joint space in a linear fashion → with some pooling in the inferior recess.*

Cervical C3/C4 Facet Injection

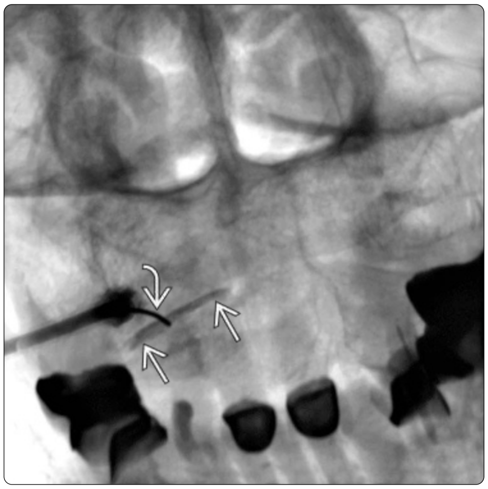


Cervical Occiput/C1 Facet Injection

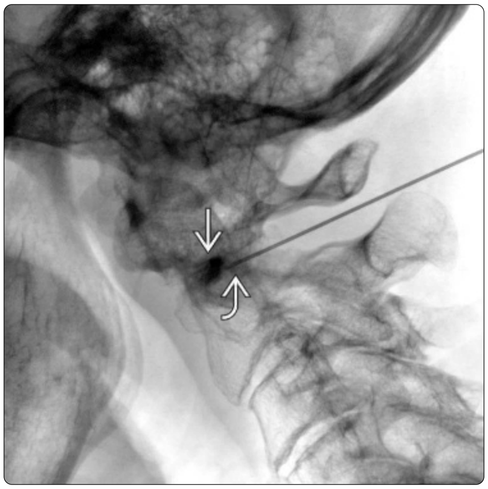


(Left) *Companion AP fluoroscopic radiograph from the same patient again demonstrates the position of the needle tip ↪ and the linear contrast spread within the joint space →.* **(Right)** *Lateral fluoroscopic spot radiograph obtained in a patient, who is status post C1-C2 fusion and C3-C6 anterior cervical discectomy and fusion, shows contrast in the occiput/C1 facet joint →. Note that the contrast in the joint assumes a linear configuration spreading away from the needle tip within the joint space.*

Cervical C1/C2 Facet Injection



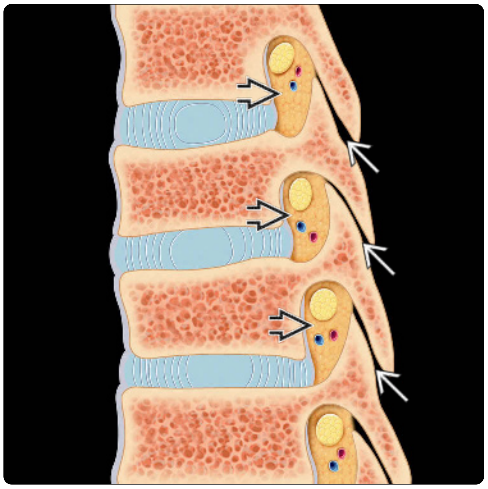
Cervical C1/C2 Facet Injection



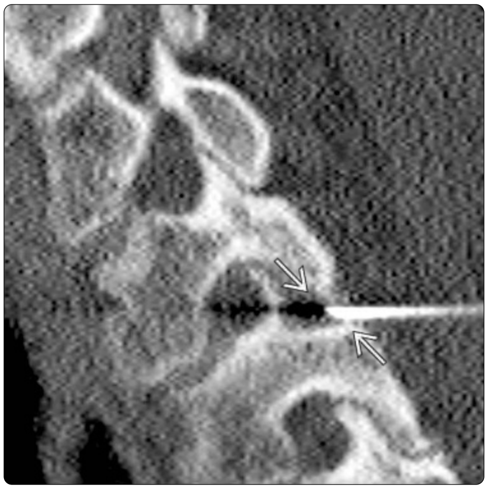
(Left) *A spot radiograph after needle placement ↪ within the left C1-C2 facet joint, with confirmatory contrast injection, shows a linear smooth contrast collection →. This appearance is characteristic of an intraarticular injection.* **(Right)** *Lateral fluoroscopic radiograph obtained in the same patient shows appropriate needle depth ↪ and contrast within the C1-C2 facet joint →. The patient's pain was reproduced by the contrast injection and significantly improved after corticosteroid injection.*

(Left) *Sagittal graphic shows the characteristic appearance of the thoracic neural foramina. Note the steep angulation of the thoracic facet joints ➔ and their relationship to the bony neural foramina ⇒ and their contents.* **(Right)** *A sagittal reformatted NECT confirms an intraarticular needle tip placement ➔. The needle was initially placed with axial imaging. Two planes of imaging can be helpful for determination of needle tip positioning, particularly if contrast injection is not being performed.*

Thoracic Normal Facet Joint Anatomy

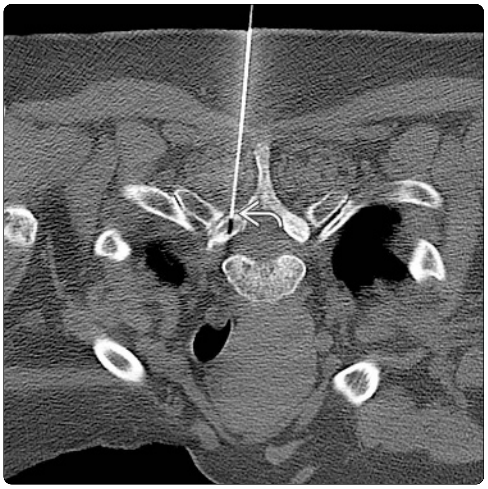


Thoracic Intraarticular Needle Placement

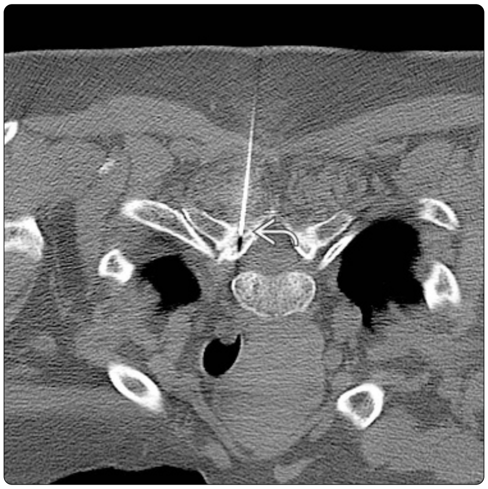


(Left) *Axial NECT obtained during CT-guided needle placement shows the needle tip ↪ immediately superficial to and along the medial margin of the targeted thoracic facet joint.* **(Right)** *Axial NECT shows the desired needle tip position obtained after "walking" the needle slightly laterally and cephalad, at which time the needle was felt to "pop" into the joint space. This image confirms that the needle tip now lies within the facet joint ↪.*

Thoracic Needle Advancement

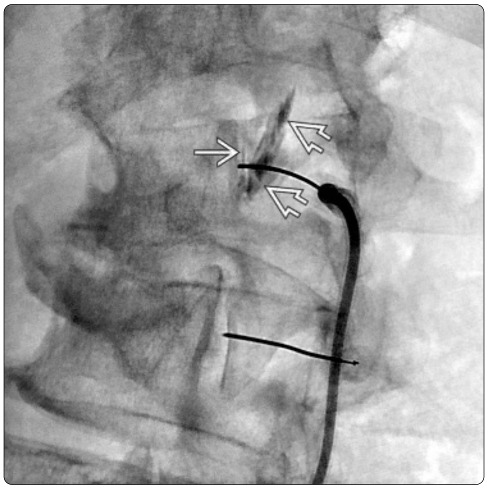


Thoracic Intraarticular Needle Placement

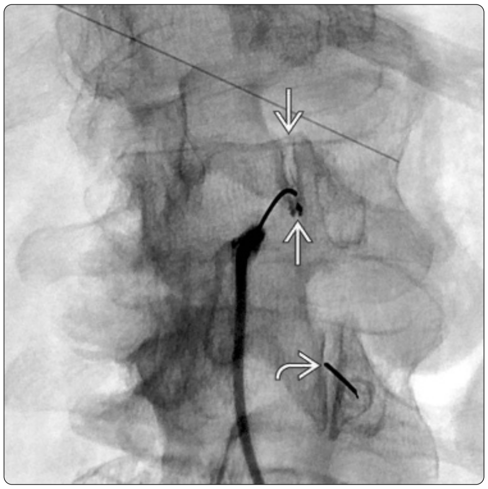


(Left) *An oblique view obtained during a left-sided facet joint injection shows the presence of extraarticular contrast ⇨ from an earlier injection with intraarticular opacification ➔ after the needle was advanced into the joint space.* **(Right)** *In this patient, contrast is injected into the right T12-L1 facet joint ➔. Both the T12-L1 and L1-L2 facet joints are well profiled in this projection, and the latter needle appears well positioned in the upper 1/3 of the joint ↪ before contrast injection.*

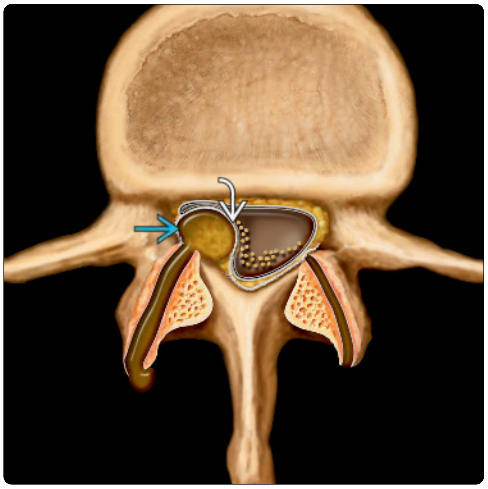
Thoracic Facet Injection (Oblique)



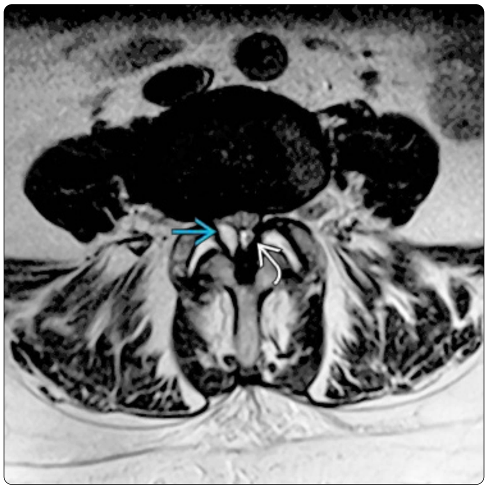
Thoracic Facet Injection (Oblique)



Lumbar Synovial Cyst

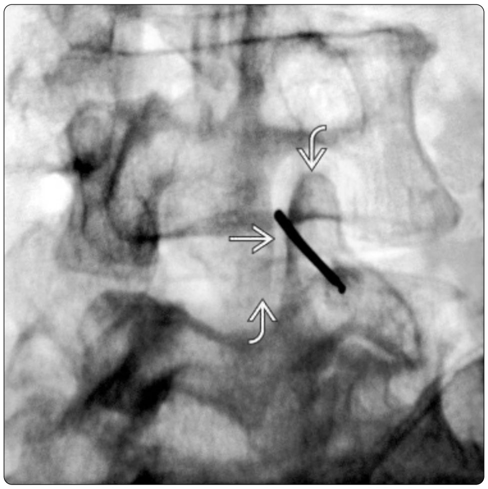


Lumbar Synovial Cyst (Axial T2 MR)

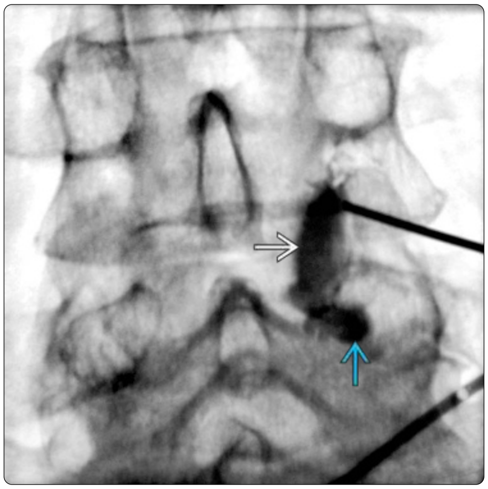


(Left) *Axial graphic depicts a synovial cyst* ⇨ *involving a degenerated right facet joint. The synovial fluid expands the right facet joint, extending into the subarticular recess in a loculated collection. The cyst results in a mass effect* ➡ *upon the thecal sac and may be clinically symptomatic.* **(Right)** *Axial T2WI MR shows a right L4-L5 synovial cyst* ⇨*, which results in a dorsolateral spinal canal stenosis. Note that there is also significant anteromedial displacement of the thecal sac* ➡ *as a result of the mass effect from the synovial cyst.*

Lumbar Needle Positioning (Oblique)

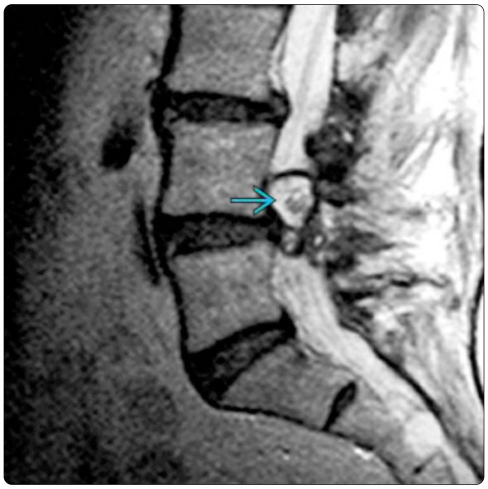


Lumbar Contrast Injection (Facet Joint and Synovial Cyst)

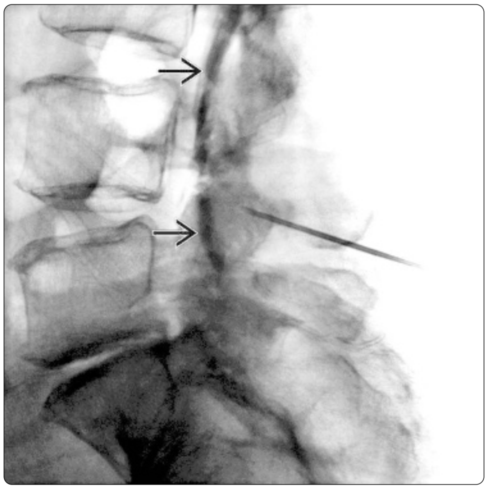


(Left) *Oblique fluoroscopic radiograph shows a 22-gauge spinal needle passing between adjacent articular facets* ➡ *into the right L4-L5 facet joint* ➡*. Correlation with lateral imaging is helpful in determining the correct needle depth.* **(Right)** *AP fluoroscopic spot radiograph shows accumulation of contrast within the facet joint* ➡*, extending caudally into a focal collection* ⇨ *consistent with a synovial cyst.*

Lumbar Synovial Cyst (Sagittal TR MR)



Lumbar Synovial Cyst Rupture (Epidurogram)



(Left) *A sagittal T2WI MR in the same patient shows a lobulated, hyperintense mass* ⇨ *in the spinal canal at the L4-L5 level. Additional MR images that were obtained confirmed that this structure was contiguous with the facet joint and represented a synovial cyst.* **(Right)** *Lateral fluoroscopic spot radiograph shows contrast* ⇨ *extending cranially and caudally within the epidural space. This is a characteristic finding following a successful therapeutic cyst rupture.*

Celiac Plexus Block

KEY FACTS

TERMINOLOGY

- **Celiac plexus**: Largest visceral nerve network, which provides sympathetic, parasympathetic, and visceral sensory afferent fibers to upper abdomen
- **Celiac plexus neurolysis**: Destruction of celiac plexus via direct injection of ethanol, usually via CT guidance

PREPROCEDURE

- Indications
  - Palliation of intractable abdominal pain due to upper abdominal visceral source
    - Most commonly: Primary pancreatic malignancies
  - Opioid-induced complications related to treatment of pain from upper abdominal visceral source
    - Goal is to reduce pain such that opioid use (and associated side effects) can also be reduced

PROCEDURE

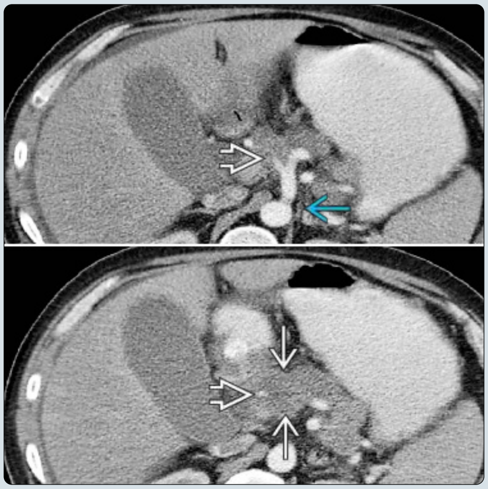
- Most common approach: Bilateral posterior paravertebral antecrural access with patient in prone position
  - Organ traversal acceptable approach if no other appropriate path exists
- Local injection of lidocaine followed by 100% ethanol
- Postprocedure imaging confirms diffusion of ethanol

OUTCOMES

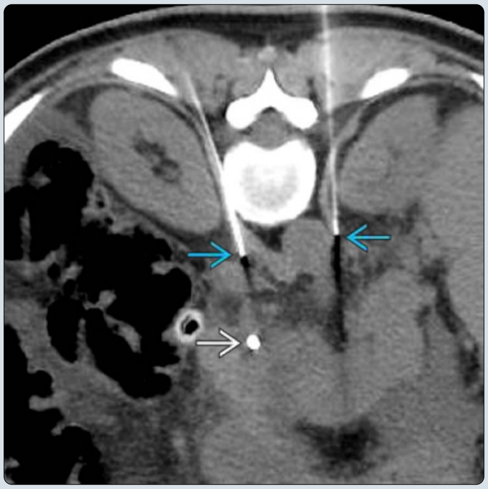
- Technical success: > 90%
- Clinical success: 70-90%
  - Defined as improved pain control &/or reduction in narcotic usage, **not** complete pain relief
- Minor complications
  - Mild back or shoulder pain: 96%
  - Orthostatic hypotension: 10-52%
  - Transient diarrhea: 44%
- Major complications: < 2% of all procedures

(Left) *This 53-year-old man presented with intractable abdominal pain due to pancreatic carcinoma. CECT obtained at the celiac axis (top) and cranial to the SMA origin (bottom) shows a hypoattenuating mass in the pancreatic body* ➡ *encasing the common hepatic artery* ⇨*. The left celiac ganglion* → *can be seen anterolateral to the aorta.* **(Right)** *Following percutaneous paravertebral insertion, 21-g Chiba needles are advanced to the antecrural, preaortic space* →*. Partially visualized biliary stent* ➡ *is also noted.*

Posterior Paravertebral Approach (CT Localization)

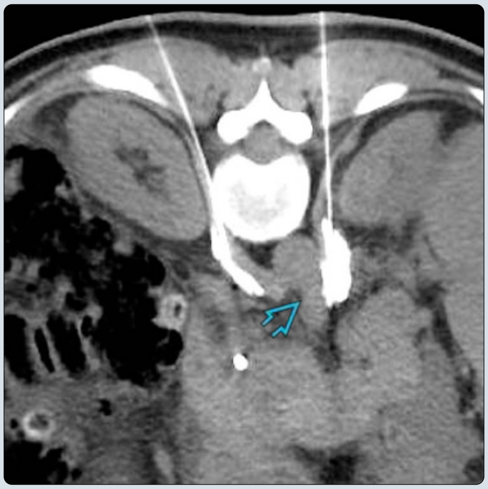


Posterior Paravertebral Approach (Needle Advancement to Antecrural Space)

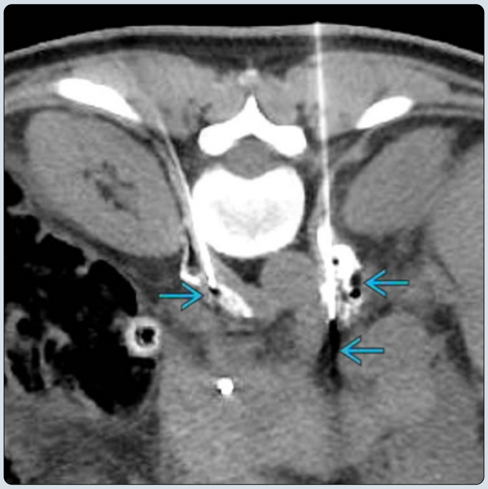


(Left) *Needle position was confirmed via injection of dilute contrast, which freely diffuses along the antecrural space. Note the origin of the celiac artery* ⇨*, the most reliable landmark for the location of the celiac plexus.* **(Right)** *Following the injection of 7 cc of lidocaine into each needle, 30 cc (15 cc each needle) of the neurolytic agent (100% ethanol) was injected. The ethanol* → *has an attenuation similar to air and is noted to freely diffuse away from the needle, an indicator of technical success.*

Posterior Paravertebral Approach (Contrast Injection to Confirm Location)



Posterior Paravertebral Approach (Ethanol Injection)



Celiac Plexus Block

TERMINOLOGY

Definitions

- **Celiac plexus**: Largest visceral nerve network, which provides sympathetic, parasympathetic, and visceral sensory afferent fibers to upper abdomen
  - Main target of pain signals in upper abdominal organs
    - Pain from organ → visceral afferent fibers → celiac plexus → splanchnic nerves → spinal cord
    - Serves pancreas, liver, biliary tract, gallbladder, spleen, adrenals, kidneys, mesentery, stomach, and bowel proximal to transverse colon
  - Bilateral retroperitoneal celiac ganglion within **antecrural** space, anterolateral to aorta
    - 94% located at level of T12 or L1
    - 0.5-1.0 cm below celiac artery
      - Location of celiac artery, not vertebral body level, considered most reliable landmark for celiac plexus
    - Left celiac ganglion: Anteromedial to left adrenal, between adrenal and left diaphragmatic crus
      - Slightly more caudal than right in most cases
      - Visualized in up to 89% by CT
    - Right celiac ganglion: Anteromedial to right adrenal, between IVC and right diaphragmatic crus
      - Visualized in up to 67% by CT
  - Imaging appearance
    - Multilobulated structures similar to limbs of adrenal glands, averaging 2.7 cm in length
    - CT
      - Unenhanced and portal venous phases: Isoattenuating to adrenal glands
      - Delayed phase (10 min post contrast): Hyperattenuating to adrenal glands
    - US: Hypoechoic, multilobulated structures or small spheres with hypoechoic bands
- **Splanchnic nerves**: Paired visceral nerves, which transmit pain information from celiac plexus to spinal cord
  - Greater splanchnic nerves (T5-T9), lesser splanchnic nerves (T10-T11), and least splanchnic nerves (T12)
  - Located within **retrocrural** space at approximately same level as celiac plexus
- **Hypogastric plexus**: Responsible for pain transmission from bowel distal to transverse colon, as well as pelvic organs
  - Explains why disruption of celiac plexus only results in upper abdominal visceral denervation
- **Celiac plexus neurolysis**: Permanent destruction of celiac plexus, usually via direct injection of ethanol, resulting in disruption of pain transmission from upper abdominal viscera due to irreversible neuronal damage
  - Generally used for palliative pain control in patients with upper abdominal malignancies
  - Most commonly performed via CT-guided percutaneous technique
- **Celiac plexus block**: Temporary disruption of celiac plexus, via direct injection of corticosteroids or long-acting anesthetics, resulting in pharmacologic block of pain transmission from the upper abdominal viscera without neuronal damage

PREPROCEDURE

Indications

- Pain: Palliation of intractable abdominal pain due to upper abdominal visceral source
  - Advanced stage or inoperable upper abdominal malignancies
    - Most commonly used for primary pancreatic malignancies
      - Also used in case of primary gastric, esophageal, or biliary malignancies
    - Metastatic liver cancer
    - Retroperitoneal lymph node metastases
  - Chronic pancreatitis
- Opioid-induced complications: Related to treatment of pain from upper abdominal visceral source (e.g., severe constipation, altered mental status, decreased alertness)
  - Goal is to reduce pain such that opioid use (and therefore unwanted side effects) can also be reduced
- Nausea/vomiting: Palliation of severe, intractable nausea/vomiting in patients with inoperable pancreatic cancer
  - Uncommonly seen in isolation; usually occurs in addition to intractable abdominal pain ± opioid-induced complications

Contraindications

- Absolute
  - Severe uncorrectable coagulopathy
  - Severe local or intraabdominal infection
  - Bowel obstruction
    - Increased risk of perforation due to common effects on bowel motility
- Relative
  - Abdominal aortic aneurysm or aortic mural thrombus
  - Eccentric origin of celiac axis
  - Obscuration of retroperitoneal fat planes by large soft tissue masses

Preprocedure Imaging

- Review any prior MR, CT, or US for
  - Location of celiac ganglion
    - Can be directly visualized on CT in most patients
    - Otherwise inferred by location of celiac axis
      - Evaluate for celiac axis anomalies, which could mean anomalous location of celiac plexus
  - Procedural planning including possible need for alternate approach, including organ traversal
  - Presence of other vascular anomaly (e.g., aortic aneurysm)

Getting Started

- Things to check
  - Procedure indications, including clear upper abdominal visceral source for pain
  - Allergies
  - Labs and medications, based upon "moderate risk of bleeding" per SIR consensus guidelines
    - Labs
      - Complete blood count (CBC): Platelet count > 50,000/ μL
      - International normalized ratio (INR): ≤ 1.5

    - Medications
      - ☐ Ticlopidine: Withhold 7 days before procedure
      - ☐ Dabigatran & fondaparinux: Withhold 2-3 days before procedure (or 3-5 days if CrCl < 50 mL/min)
      - ☐ Clopidogrel: Withhold 5 days before procedure
      - ☐ Low molecular weight heparin (therapeutic): Withhold 12 hours before procedure
      - ☐ Aspirin: Do not withhold
  - ○ Antibiotic prophylaxis
    - SIR guidelines: Not routinely recommended
    - Exceptions: Traversal of stomach/bowel or transintervertebral disc approach
      - ☐ Prophylaxis routinely recommended
      - ☐ 1 g cefazolin suggested
  - ○ Informed consent: Celiac plexus neurolysis-specific considerations
    - Transient orthostatic hypotension and diarrhea
    - Nontarget delivery of neurolytic
    - Planned or unplanned organ traversal
    - Failure to improve pain control despite technical success
- Equipment list
  - ○ Radiopaque grid
  - ○ #11 blade
  - ○ 21-g Chiba needle(s)
  - ○ 5- to 10-cc syringes
  - ○ Agents for injection
    - Lidocaine: Both for subcutaneous and target injection
    - Dilute contrast
    - 100% ethanol
    - Normal saline

PROCEDURE

Patient Position/Location

- Most common approach: Bilateral posterior paravertebral antecrural access with patient in prone position
- Posterior access
  - ○ Patient in prone or lateral decubitus position
  - ○ Approach options
    - Bilateral paravertebral antecrural
      - ☐ Most common
      - ☐ Least risk of organ traversal or injury in most patients
    - Bilateral paravertebral retrocrural
      - ☐ Results in splanchnic neurolysis, not celiac plexus neurolysis, which is less effective
      - ☐ Consider when antecrural approach is blocked by anatomic distortion of preaortic space by extensive tumor spread
    - Transintervertebral disc
      - ☐ Unilateral or bilateral
      - ☐ Consider when paravertebral needle path blocked by osseous structures
      - ☐ May not be possible in patients with advanced degenerative disease
    - Transaortic
      - ☐ Accomplished via initial left paravertebral or transintervertebral disc access
      - ☐ Consider in rare cases when other safe access paths cannot be found
- Anterior access
  - ○ Patient in supine position
    - May be preferred in cases where patient unable to tolerate prone positioning, such as due to pain or respiratory distress
  - ○ Approach will often require traversal of organ(s)
    - Commonly stomach, bowel, or liver
      - ☐ Less risk of kidney/adrenal injury than with posterior approach
    - Still generally regarded as safe
      - ☐ These organs are commonly traversed in other percutaneous procedures (such as biopsy or abscess drainage)
      - ☐ Although associated with greater risk than posterior approach, palliative benefit of procedure still outweighs risk
      - ☐ May require additional postprocedure monitoring or antibiotic prophylaxis

Procedure Steps

- General
  - ○ Choose imaging modality
    - CT (preferred)
      - ☐ Sensitive visualization of anatomy, low cost, ease of use
      - ☐ Can easily change access or approach, if needed
      - ☐ Radiation risk outweighed by palliative benefits
    - US
      - ☐ Less sensitive visualization of regional anatomy than CT, increasing risk of complication
      - ☐ Most susceptible to artifact following injection of anesthetic or neurolytic
      - ☐ Dependent on patient body habitus
      - ☐ Could be considered for use by experienced operator in event CT unavailable or bedside procedure must be performed
    - MR
      - ☐ Despite more sensitive visualization of soft tissues, has not been shown to improve technical or clinical success over CT
      - ☐ Increased cost, decreased ease of use; requires specialized equipment
      - ☐ Could be considered for complicated cases, such as those requiring transintervertebral disc access
    - Fluoroscopy: Not recommended due to substantial risk of complication
  - ○ Perform preliminary imaging to determine approach and access path
  - ○ Sterilely prep skin and drape field
  - ○ Administer 1% lidocaine at skin site and along desired subcutaneous tract
  - ○ Skin nick with #11 blade
- Percutaneous access
  - ○ Insert 21-g Chiba needle into skin site
    - Advance sequentially under CT guidance
      - ☐ Target: Antecrural space between origins of celiac and superior mesenteric arteries, 1-2 cm anterior to aorta
    - Once in desired location, aspirate to exclude intravascular location of needle tip
      - ☐ If blood return, readjust needle position

  - Confirm appropriate position of needle tip
    - Inject ~ 5 cc of dilute contrast
      - ☐ Use dilute (1:10) contrast to saline to limit streak artifact
      - ☐ Inject contrast through each needle placed
    - Contrast should flow freely away from needle tip within antecrural space
    - Readjust needle tip and repeat contrast injection as needed until position confirmed
  - Hydrodissection can be used as adjunctive method to achieving safe needle trajectory
    - Injection of saline along desired path helps to move visceral structures away from needle trajectory
- Neurolysis
  - Inject 5-10 cc of long-acting analgesic
    - Inject 5-10 cc through each needle placed
    - Reduces procedural pain associated with neurolysis
    - Commonly used agents include lidocaine or bupivacaine
  - Reconfirm needle tip position
    - Rescan after injection of analgesic
    - Aspirate to exclude intravascular position
      - ☐ If blood return, will need to reposition as above
  - Inject neurolytic agent
    - Most commonly: 100% ethanol
      - ☐ Must be > 40% ethanol to achieve neurolysis
      - ☐ Phenol has also been used but is less efficacious than ethanol
    - 40 cc total preferred for antecrural approach
      - ☐ Split between 2 needles if using bilateral access (i.e., 20 cc each side)
      - ☐ Reduce amount to 15-20 cc for retrocrural approach
    - No resistance should be met during injection
      - ☐ If resistance, pause injection and reimage to assess needle location
    - Transient pain and increase in heart rate can occur during injection
      - ☐ Usually returns to baseline within 1-2 min
- Postneurolysis
  - Repeat CT imaging
    - Neurolytic agent should diffuse freely within preaortic space
      - ☐ Ethanol will have attenuation similar to air
    - Evaluate for any immediate complications or nontarget administration of neurolytic agent
  - Inject ~ 5 cc of normal saline prior to removing needle(s)
    - Prevents residual neurolytic agent from leaking around needle tract as it is withdrawn

Findings and Reporting

- Report approach type and injection location (antecrural/retrocrural, unilateral/bilateral)
  - Appropriate location confirmed via visualization of dilute contrast in desired space
- Report amount of dilute contrast, local anesthetic, and neurolytic delivered
- Findings on postprocedure imaging
  - Extent of diffusion of neurolytic agent
    - Associated with technical success
  - Evaluation of any traversed organs for injury (e.g., presence/absence of subcapsular hematoma)
  - Description of any nontarget injection of neurolytic agent

Alternative Procedures/Therapies

- Radiologic
  - Celiac plexus block
    - Only offers temporary pain relief via pharmacologic blockade
    - Similar technique and risks without any long-term benefit
    - May be beneficial to perform block in cases of atypical description of pain/nonmalignant pain/vague abdominal pain; if block improves pain, then staged neurolysis can be considered
- Surgical
  - Surgical celiac plexus neurolysis
    - Requires invasive surgery with substantially more risk than percutaneous approach without any added benefit
    - No additional benefit in morbidity/mortality when performed in conjunction with definitive surgical resection of tumor (i.e., when performed during Whipple)
- Other
  - Endoscopic US (EUS)-guided celiac plexus neurolysis
    - Increased patient risk due to
      - ☐ Need for intubation and increased procedural sedation
      - ☐ Decreased anatomic resolution associated with EUS
    - Decreased success due to
      - ☐ Decreased anatomic resolution associated with EUS
      - ☐ Inability to appreciate altered anatomy due to mass effect/invasion by tumor
      - ☐ "Snowstorm effect": Obscuration of antecrural space anatomy hyperechoic neurolytic solution
    - Could be considered in case of concurrent need for other endoscopic intervention (e.g., biliary stent placement) with qualified operator

POST PROCEDURE

Things To Do

- Bed rest and monitoring for at least 12 hours
- Monitor for orthostatic hypotension, fluid resuscitate
- Focused neurologic exam prior to discharge

OUTCOMES

Problems

- Technical failure
  - Uncommon
  - Factors improving technical success
    - Image-guided technique (CT/MR > EUS > US > fluoro)
    - Adequate amount of neurolytic injected
      - ☐ Improved long-term outcomes with total of 40 cc in antecrural space vs. 20 cc
    - Satisfactory diffusion of neurolytic agent following injection
- Clinical failure
  - More common due to multifactorial etiology of pain

    - Only visceral pain information transmitted through celiac plexus disrupted
      - ☐ Nonvisceral upper abdominal pain unaffected (e.g., abdominal wall, musculature, etc.)
      - ☐ Visceral pain transmitted through other nerve pathways also unaffected (e.g., hypogastric plexus for lower abdominal/pelvic organs)
  - Factors improving clinical success
    - Antecrural injection (celiac plexus neurolysis) vs. retrocrural injection (splanchnic neurolysis)
    - Lack of distant metastatic disease
      - ☐ Increases likelihood that pain signals are passing through celiac plexus and will thus improve with celiac plexus neurolysis
    - Short duration of disease
      - ☐ Reportedly most successful within 2 months of pain onset
      - ☐ Effects likely compounded by associated decreased total usage of narcotics

Complications

- Minor complications
  - Mild back or shoulder pain: 96%
    - Due to direct neurolysis and referred pain from diaphragmatic irritation
    - Usually resolves within 72 hours
  - Orthostatic hypotension: 10-52%
    - Due to vasodilation from decreased sympathetic tone
    - Can be prevented/treated with adequate hydration and postprocedure bed rest
    - Usually resolves within 12 hours
  - Transient diarrhea: 44%
    - Unopposed parasympathetic tone results in decreased intestinal transit time and increased peristaltic activity
    - Although listed as complication, often welcome side effect as many patients already suffering from opioid-induced constipation
    - Usually resolves in days to weeks
      - ☐ Chronic diarrhea very rarely reported
- Major complications: < 2% of all procedures
  - Neurologic injury: < 1%
    - Immediate lower extremity paralysis with possible loss of bladder/bowel function
    - Due to direct spinal cord damage via inadvertent injection into spinal artery or indirectly via spinal artery vasospasm from local irritation resulting in spinal cord ischemia or infarct
  - Diaphragmatic paralysis: Extremely rare
    - Immediate dyspnea with paradoxical movement of diaphragm with respiration
      - ☐ Effects may range from symptomatic dyspnea/orthopnea to acute respiratory failure and dependence on mechanical ventilation
    - Few documented case reports, most occurring during EUS-guided procedures, which attribute complication to direct neurolysis of phrenic nerves
  - Arterial injury: Extremely rare
    - Unlikely with use of CT/MR and experienced operator
- Approach-specific complications
  - Posterior
    - Retroperitoneal hematoma or abscess
    - Pneumothorax
    - Traversal of organs causing injury &/or hemorrhage: Adrenals or kidneys
      - ☐ Generally well tolerated given small needle size
      - ☐ Major complications associated with specific traversal of renal hilum or pelvicalyceal system
    - Disc injury in case of transintervertebral disk approach
  - Anterior
    - Traversal of organs causing injury &/or hemorrhage: Liver, stomach, bowel, pancreas
      - ☐ Generally well tolerated given small needle size
      - ☐ Major complications associated with specific traversal of portal hilum, dilated biliary ducts, or fecal-filled colonic loops
    - Pancreatitis in case of transpancreatic approach or direct tumor injection

Expected Outcomes

- Technical success: > 90%
- Clinical success: 70-90%
  - Immediate pain relief: Due to transient effects of local anesthetic
  - Long-term pain relief: Due to permanent neurolysis
    - Defined as improved pain control &/or reduction in narcotic usage, **not** complete pain relief
    - Possible modest improvement in cancer survival, attributed to effects of decreased narcotic usage

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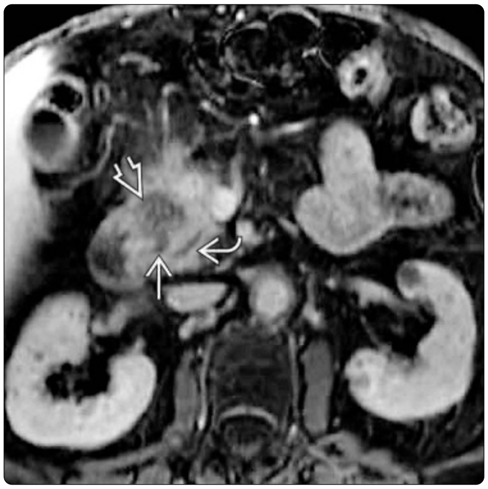
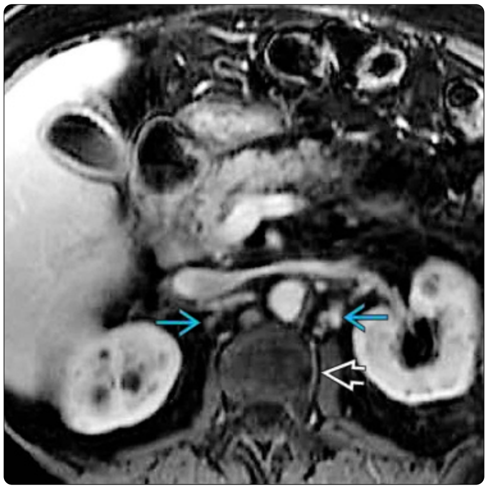
Anterior Transhepatic/Transpancreatic Approach (Tumor Localization)

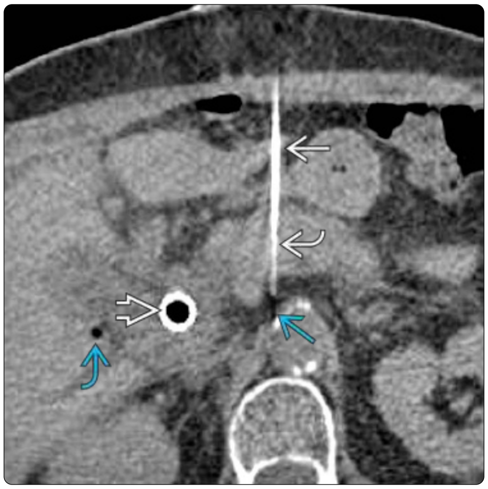


Anterior Transhepatic/Transpancreatic Approach (Celiac Ganglia Localization)

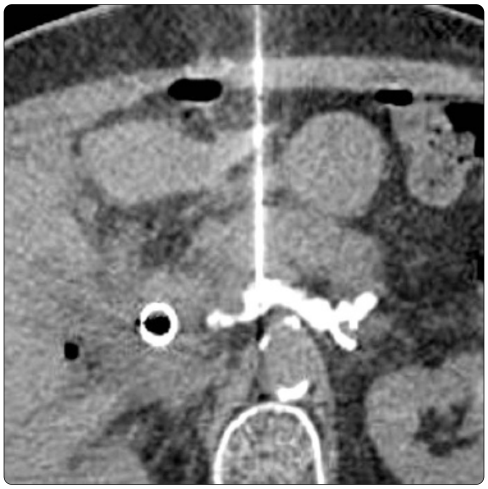


(Left) *Axial T1 C+ FS MR in a 68-year-old woman with metastatic pancreatic cancer, severe abdominal pain, and opioid-induced constipation demonstrates a hypoenhancing, obstructive pancreatic head mass* ⇨ *with resultant dilation of the common bile duct* → *and pancreatic duct* ↪ *(double duct sign).* **(Right)** *Axial T1 C+ FS MR between celiac axis and SMA shows the polylobulated celiac ganglia* → *lateral to the aorta in the antecrural space, isointense to the adrenals (not shown). Note proximity to the lumbar artery* ⇨*.*

Anterior Transhepatic/Transpancreatic Approach (Needle Advancement)

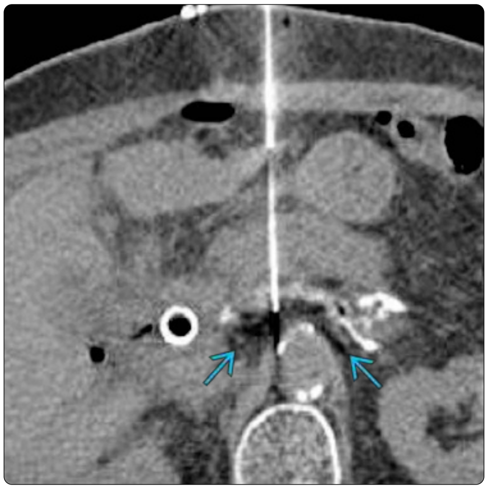


Anterior Transhepatic/Transpancreatic Approach (Contrast Injection)

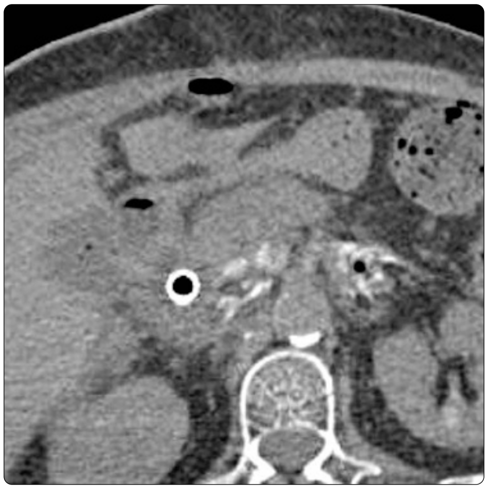


(Left) *An anterior approach was selected due to patient's inability to tolerate prone positioning. A 21-g Chiba needle was advanced to the antecrural space* → *through both the liver* → *and the pancreas* ↪*, just caudal to the celiac axis origin (not shown). Note is made of biliary stent* ⇨ *and preexisting pneumobilia* ↪*.* **(Right)** *Dilute contrast was injected to confirm appropriate position of the needle tip. Contrast flows freely away from the needle along the antecrural space, as expected.*

Anterior Transhepatic/Transpancreatic Approach (Ethanol Injection)



Anterior Transhepatic/Transpancreatic Approach (Final Image)



(Left) *Following the injection of 5 cc of lidocaine, approximately 20 cc of 100% ethanol was injected. Postprocedure imaging shows adequate diffusion of the ethanol (similar in attenuation to air) along the bilateral antecrural space* →*.* **(Right)** *Postprocedure imaging following the removal of the needles did not demonstrate any immediate postprocedure complications. Despite traversal of the liver and pancreas, the patient did not have any major postprocedure complications.*

Basic Arthrographic Techniques

KEY FACTS

PREPROCEDURE

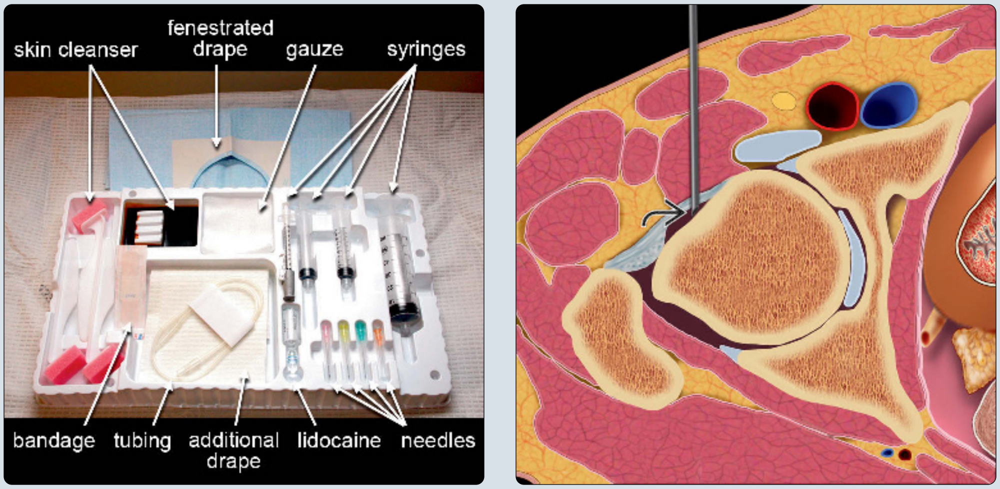
- Diagnostic arthrogram
  - Injury to cartilage, ligaments, tendons, capsule
  - Usually combined with CT or MR
- Joint aspiration (arthrocentesis)
  - Fluid analysis for joint infection, crystalline disease
- Therapeutic injection
  - Corticosteroid, hyaluronic acid preparations, &/or anesthetic
- Coordinate with MR staff (if MR arthrogram)
  - Generally, MR should be completed within hour after joint injection

PROCEDURE

- Use 20- to 22-g needles for injection of deep joints
- Use 22- to 25-g needles for superficial joint injections
- Use 18-g needle to aspirate for infection
- Choice of approach based on
  - Comfort, neurovascular avoidance, directness
- CT arthrography
  - Dilute full-strength iodinated contrast 1:1 with saline
- MR arthrography
  - 1:200 dilution of gadolinium-based contrast
  - Diluent: Either pure saline or 50% iodinated contrast & 50% saline

OUTCOMES

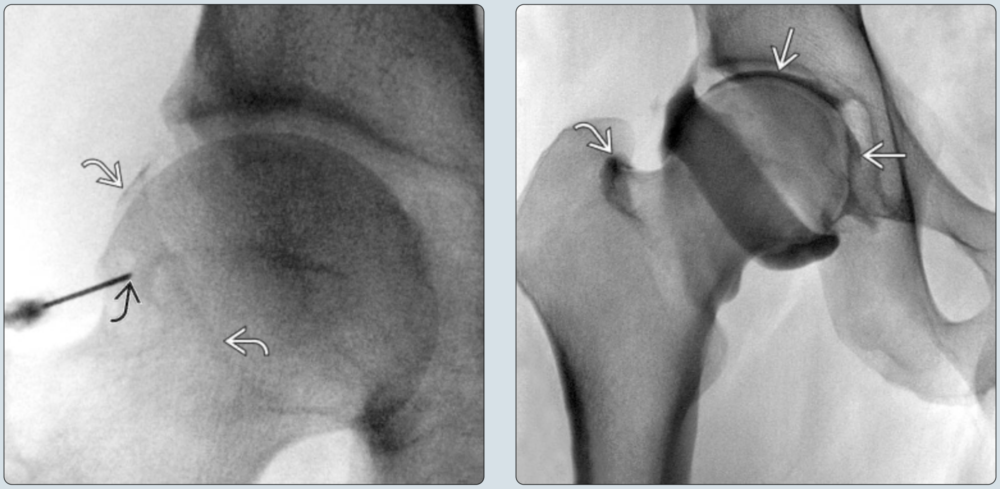
- Extremely high technical success rate
- Complications
  - Postprocedure pain (common)
  - Numbness, tingling, transient muscle weakness of extremity (due to local anesthetic)
  - Septic arthritis (rare)
  - Injury to adjacent structures: Use of standard approaches improves safety
  - Contrast reaction (rare inside joint)



Arthrogram Tray

Ideal Needle Tip Position

(Left) *Clinical photograph shows the labeled contents of a typical arthrogram tray. These disposable trays provide almost all items needed for performing arthrography. Contrast medium is not included with the tray.* **(Right)** *Axial graphic of the hip demonstrates the ideal position of the needle tip ⇨, where the bone curves away from the horizontal (i.e., concave). The bevel of the needle faces the curve of the bone.*



Intraarticular Contrast (Early Imaging)

Intraarticular Contrast (Late Imaging)

(Left) *AP hip arthrogram shows optimal needle position, where the femoral head curves away from horizontal. This allows the proximal portion of bevel, as well as the needle tip ⇨, to lie inside of the joint capsule. Contrast ➡ flows away from the needle as it is injected and conforms to the joint contour, confirming an intraarticular position.* **(Right)** *Anteroposterior right hip arthrogram shows the ideal amount of joint distention by the injected contrast, filling joint recesses ➡ and extending between articular surfaces ➡.*

TERMINOLOGY

Definitions

- **Arthrography**: Imaging examination of joint
  - Contrast material injected to opacify/delineate joint
    - Agents include iodinated contrast, gadolinium, air
  - Imaging options
    - Fluoroscopy and radiography
    - CT
    - MR

PREPROCEDURE

Indications

- Diagnostic arthrogram
  - Injury to cartilage, ligaments, tendons, capsule
  - Usually combined with CT or MR
- Joint aspiration (arthrocentesis)
  - Fluid analysis for joint infection, crystalline disease
- Therapeutic injection
  - Corticosteroid, hyaluronic acid preparations, &/or anesthetic

Contraindications

- Surrounding/overlying soft tissue infection
  - Never pass needle through infected tissue to access a joint; may cause joint infection
- Coagulopathy (relative contraindication)
  - Arthrography and arthrocentesis are very low bleeding risk procedures
  - Anticoagulants are typically not held
  - Routine labs not typically obtained prior to procedure; however, if patient on warfarin, check last international normalized ratio (INR) to ensure within therapeutic range

Getting Started

- Things to check
  - Medical history: Bleeding risk, medication list
  - Allergies
    - Exclude any history of allergy to contrast or anesthetic agent
  - Laboratory parameters
    - Most recent INR (if patient on warfarin)
  - Consent obtained, including discussion of
    - Risk of infection [rare (1:20,000)]
    - Local bruising (uncommon, treated with ice)
    - Allergic reaction (uncommon in joint)
    - Numbness, tingling, transient muscle weakness
      - From anesthetic injection
    - Postprocedure pain
      - Common, may be prolonged
      - Management with acetaminophen, nonsteroidal antiinflammatory medications
  - Coordinate with MR staff (if MR arthrogram)
    - Gadolinium absorbed by body relatively quickly
    - Generally, MR should be completed within hour after injection
- Medications
  - 1% lidocaine HCl (if steroid injection, ensure preservative-free)
  - Sodium bicarbonate; mix 1:9 with lidocaine
    - Optional, but diminishes "sting"
  - Nonionic iodinated contrast
  - Saline
  - Gadolinium-based contrast (for MR arthrography)
  - Therapeutic injection
    - Corticosteroid (type/dose depends on joint, preference)
      - Do not inject steroid if infection suspected
      - Corticosteroid can be added to diagnostic arthrogram without degrading image quality
    - Long-acting anesthetic
      - Ropivacaine 0.5%
      - Some studies have shown decreased toxicity to chondrocytes in vitro with ropivacaine compared to bupivacaine
  - All medications injected should be single-use vials
- Equipment list
  - Guidance modality equipment
    - Fluoroscopy (most commonly used)
    - CT
    - US
  - Positioning devices (towels, sandbag, pillows, wedges, tape)
  - Skin localizer: BB on piece of tape or other marker
  - Indelible marker to mark skin
  - Povidone-iodine skin cleanser or substitute
  - Needle for accessing joint (gauge/length depends on joint)
    - 18 g for aspiration of suspected infection
    - 20-25 g may be used for diagnostic exam
      - 22 g recommended for deep joints (e.g., hip)
      - 25 g recommended for superficial joints (e.g., wrist)
    - Needle length based on joint, patient size
  - Procedure tray
    - Sterile fenestrated drape
    - Gauze; Band-Aid
    - Miscellaneous needles
      - 18 g for drawing medications/contrast
      - 25 g for local anesthetic injection
    - Syringes
      - 1 mL for gadolinium
      - 5 mL for local anesthetic, corticosteroid
      - 5-10 mL for aspiration of joint fluid
      - 10-20 mL for contrast mixture

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Choose approach based on
    - Patient comfort: Must be able to easily maintain position
    - Avoidance of vessels and nerves
    - Avoidance of overlying infection
    - Straight approach to joint of concern when using fluoroscopy
      - Needle oriented vertically rather than obliquely
    - Can use oblique approach to joint if visualizing with US

Equipment Preparation

- Prepare contrast solution
  - Plain arthrography
    - Full-strength iodinated contrast medium
  - CT arthrography
    - Iodinated contrast diluted 1:1 with saline or anesthetic
  - MR arthrography
    - 1:200 dilution of gadolinium
    - Diluent: 50% nonionic contrast/50% saline
      - e.g., 0.1 mL gadolinium, 10 mL nonionic iodinated contrast, 10 mL saline
      - May replace some diluent with anesthetic
    - Alternatively, some radiologists prefer 2 separate contrast syringes
      - One syringe of full-strength nonionic iodinated contrast to confirm needle position
      - One syringe of diluted gadolinium (1:200 dilution) for MR (e.g., 0.1 mL gadolinium and 20 mL saline)
- Attach contrast-filled syringe to flush tubing and flush with contrast, ensuring no air bubbles

Procedure Steps

- Obtain informed procedural consent
- **Perform "timeout" procedure**
  - Verify correct patient
  - Verify correct procedure/correct site
  - Confirm any pertinent allergies
  - Confirm correct equipment/medications available
- **Fluoroscopic-guided injections**
  - Position patient and prepare injection site
    - Use straight, vertical approach (e.g., bulls-eye) to joint of concern
    - Choose location over bone, not joint space
      - Provides stop, so needle will not pass too deep
    - Choose location where bone curves away from horizontal (i.e., slight concavity)
      - e.g., superior margin of humeral head rather than center of humeral head
      - Otherwise needle tip may be in joint, but bevel may be partly extraarticular
    - Position patient so that entry site is in center of image
      - Avoids parallax
    - Localize with fluoroscope and mark overlying skin with indelible marker
    - Prep and drape site in usual sterile fashion
  - Access joint and perform contrast injection
    - Administer local anesthesia with 1-2 mL lidocaine
    - Replace anesthesia needle with needle that will be used to access joint
    - Advance needle a few cm to get adequate purchase in soft tissue, and then check needle position with fluoroscope
      - Want to see needle en face (will look like dot)
      - If shaft of needle is visible, needle is angled and must be repositioned
    - Correct for any angulation of needle, advance needle a few cm, and then check needle position with fluoroscope
    - Advance needle until it contacts bone (or prosthesis)
    - Remove inner stylet, attach flush tubing, and inject small amount of contrast while monitoring fluoroscopically
      - Contrast should flow freely away from needle and follow joint contours
      - Spontaneous return of joint fluid also confirms intraarticular positioning of needle
      - If contrast pools around needle, then needle tip is not intraarticular and must be repositioned
    - Once intraarticular positioning of needle is confirmed, inject contrast solution or corticosteroid solution (therapeutic injections)
      - Suggested contrast volumes will vary depending on joint
  - Remove needle, cleanse skin, and place bandage
  - Take any necessary spot images
- **Joint aspiration**
  - Use 18-g needle (infected fluid may be thick)
  - Avoid areas of overlying skin abnormality or cellulitis
  - Pass 18-g needle into joint
  - If fluid comes back readily, aspirate at this point
  - If no spontaneous fluid return
    - Inject small amount of iodinated contrast to verify intraarticular position
  - Aspirate again; if no return
    - Try using smaller syringe; easier to aspirate with 5-mL than 10-mL syringe
    - "Walk" needle to different regions of joint
      - Infected joint may have loculated fluid
    - Inject sterile saline; aspirate back immediately
      - Often recommended method but low yield
  - Collect specimen, and send for analysis
    - Gram stain, culture, cell count; any other requested labs

Findings and Reporting

- **Diagnostic arthrogram**
  - Abnormal communication of joint with other compartments/collections
  - Synovitis (irregular capsular margins on conventional arthrographic images)
  - Signs of arthritis; other bone abnormalities
- **Joint aspiration: Native joint or arthroplasty**
  - Character of fluid aspirated
    - Normal synovial fluid
      - Clear yellow color
      - Viscous, slightly bubbly consistency
    - Infected synovial fluid
      - May be grossly purulent or cloudy
      - May appear normal
    - Metallosis may cause dark-colored synovial fluid
      - Titanium: Dark fluid
      - Cobalt-chrome: Green-gray fluid
  - Evidence of loosening
    - Contrast extension into prosthesis/bone interface
  - Contrast extension to periarticular abscess pockets via sinus tracts

Alternative Procedures/Therapies

- Radiologic
  - US guidance

    - Avoids ionizing radiation
    - Allows direct visualization of anatomic structures, effusions
    - Helpful in MR arthrography, when patient has allergy to iodinated contrast
  - Indirect MR arthrography
    - Inject standard IV gadolinium dose
    - Contrast will be excreted by synovium into joint
    - Have patient move joint repeatedly through range of motion to increase blood flow
    - Perform MR 15-30 min after injection

OUTCOMES

Problems

- Extraarticular injection
  - Verify intraarticular position of needle prior to full injection
    - Must be familiar with normal joint contour prior to procedure
      - Other potential spaces around joint may mimic intraarticular injection
    - Pooling of contrast at needle tip is sign of incorrect needle position
  - Inadvertent intravascular needle placement
    - Contrast will fill artery/vein
      - Clears rapidly after injection

Complications

- Most feared complication(s)
  - Septic arthritis
    - Use careful sterile technique
    - Do not reuse medication vials
    - Never pass needle into joint through suspected soft tissue infection
    - Counsel patients that signs of infection may occur several weeks after arthrography
      - If small number of bacteria introduced into joint during procedure, requires time to proliferate/become symptomatic infection
- Other complications
  - Injury to adjacent structures: Use of standard approaches improves safety
    - Always consider course of adjacent nerves/vessels
  - Contrast reaction: If contrast allergy, standard premedication recommended
  - Nerve irritation
    - If needle passes through nerve
      - Patient will feel "electric shock" along nerve
      - Reposition needle, and reassure patient
  - Temporary numbness or weakness of extremity
    - Lidocaine used for local anesthetic may diffuse around nerve
    - Symptoms resolve in about 30 min
    - Assist patient off table; ensure no weakness
  - Postprocedure pain
    - May persist for several days
    - Treat with acetaminophen, nonsteroidal antiinflammatory medications
  - Soft tissue irritation from extraarticular injection
    - Typically responds to conservative management
      - Usually adequately treated with cold compresses
      - May use nonsteroidal antiinflammatory medications if needed
    - Call patient next day to verify resolution
    - If severe, dermatology consult is recommended

Expected Outcomes

- Extremely high technical success rate
  - High accuracy in diagnosing joint abnormalities
    - Dependent on technique/imaging modality used
  - Joint aspiration of fluid for analysis/culture
    - Essential in diagnosing septic arthritis

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Therapeutic Joint Injections

KEY FACTS

TERMINOLOGY

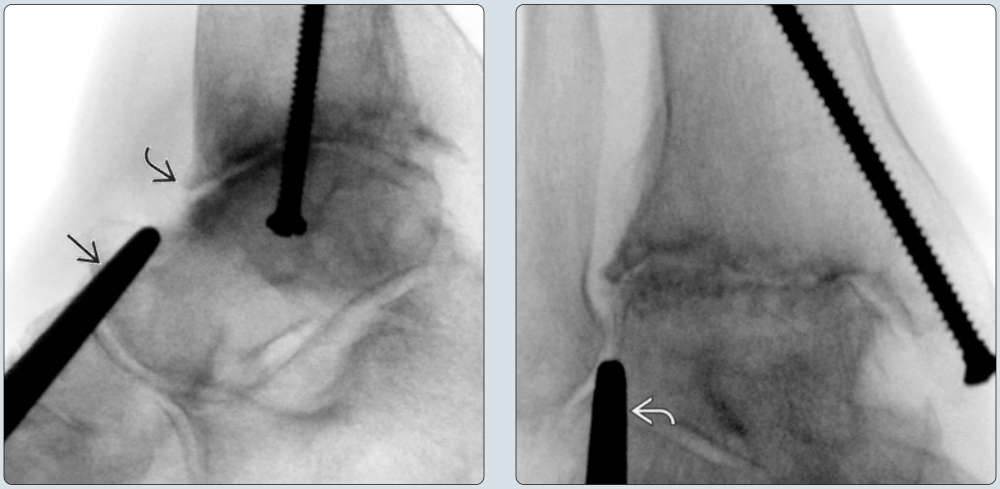
- Injection of various medications, most commonly corticosteroid, anesthetic, &/or hyaluronic acid (HA) preparation for treatment of joint pain

PREPROCEDURE

- Indications: Pain due to arthritis, other soft tissue pathology, or for determination of pain generator
- HA products vs. corticosteroids
  - HAs more expensive, slower onset of pain relief
  - 1 study suggests synergistic effect of combination HA/steroid
  - HAs may cause inflammatory response, especially with inadvertent extraarticular injection
- Commercially available HAs have various molecular weight, viscosity, resident time in joint, etc.
  - No literature to date supports substantial clinical differences based on these distinctions

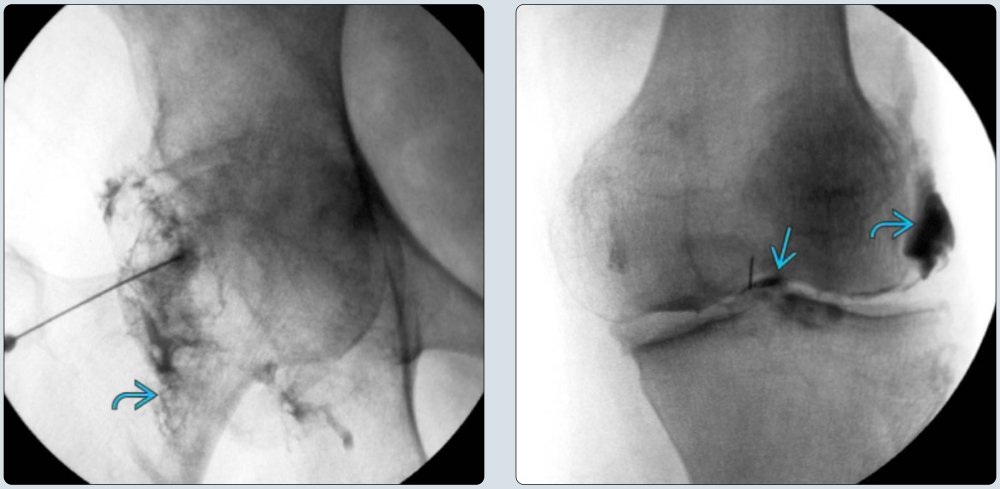
OUTCOMES

- Initial symptomatic relief from local anesthetic
  - Several hours' duration
- Variable onset of response to steroid preparation
  - Typically 2-10 days
- Duration of corticosteroid response variable
  - Typically 2-6 months
- Slow response to HA supplements
  - Typically 6 months
- Complications
  - Hyperglycemia related to corticosteroid, inflammatory response to HA, infection, bleeding, allergy


Lateral View of Ankle

Oblique View of Ankle

(Left) *Lateral radiograph in a patient with severe osteoarthritis presenting for therapeutic injection shows a hemostat → placed overlying the usual needle course. Injection here may be difficult due to large osteophytes ↪.* **(Right)** *Oblique fluoroscopic image shows a hemostat ↪ placed over an area where osteoarthritis is less severe for marking prior to joint injection. Knowing various techniques for joint entry can be particularly useful in cases with advanced osteoarthritis, where osteophytes may block typical joint access path.*


Hip Joint Injection

Knee Injection

(Left) *AP image of the hip demonstrates contrast injection into the joint for therapeutic pain relief. The irregular pattern of contrast filling ↪ within the joint indicates synovitis.* **(Right)** *AP approach for a therapeutic knee joint is noted. Contrast is seen within the joint spaces, including the central portion of the tibiofemoral joint space →, as well as tracking into the suprapatellar recess ↪.*

TERMINOLOGY

Definitions

- **Therapeutic joint injection**: Injection of various medications, most commonly corticosteroid, anesthetic, &/or hyaluronic acid (HA) preparation, for treatment of joint pain

PREPROCEDURE

Indications

- Therapeutic pain relief from variety of conditions, most commonly arthritis
- May also be requested in setting of pain due to soft tissue pathology when surgery either not desired or not possible
  - Tendinopathy, partial tears, or cases where patient is not surgical candidate
- Diagnostic and therapeutic injections
  - Injection may help determine if pain is coming from joint or extraarticular cause
  - Particularly useful in hip, if unclear whether pain is due to intraarticular pathology or other cause (lumbar radiculopathy, bursitis, etc.)

Contraindications

- Absolute contraindications
  - Active joint infection or bacteremia
  - Skin infection overlying/near injection site
  - Known sensitivity or allergy to agent(s) being utilized
- Relative contraindications
  - Anticoagulation therapy
    - Joint injections generally safe, can be performed in patients on anticoagulation if medically necessary
    - May be warranted to check labs (i.e., PT/INR) prior to procedure
    - Counsel patient on increased risk of bleeding, if appropriate, and risks vs. benefits in each clinical setting

Getting Started

- Things to check
  - Pertinent clinical history and physical examination
  - Patient allergies
  - Pertinent medications, including anticoagulants, and labs as needed
- **Anesthetic agents**
  - 1% lidocaine
    - Onset seconds to minutes, duration 60-120 min
  - Ropivacaine 0.5% or bupivacaine 0.5%
    - Some in vitro reports state ropivacaine less toxic to chondrocytes than bupivacaine
    - Equivalent analgesic effect for both agents
    - Onset 2-10 min, duration 180-360 min
  - Recommended intraarticular dose (not including corticosteroid)
    - Hip/shoulder/knee: 4-8 mL of 1% preservative-free lidocaine + 0.5% ropivacaine
      - Utilizing both anesthetics provides both immediate and medium- to long-term anesthetic properties
      - Ensures joint capacity not filled with anesthetic, which could prevent sufficient steroid administration
    - Elbow/wrist/ankle: 2-4 mL
    - Smaller joints in hands/feet: 1 mL of anesthetic
- **Corticosteroids**
  - Corticosteroid onset/duration of action varies by type
    - Onset generally 3-5 days, duration 4-8 weeks
  - No clear consensus regarding appropriate doses of steroid in small, intermediate, and large joints
  - Duration of effect theoretically inverse to solubility
  - Frequency of corticosteroid injections controversial
    - Due to concern for soft tissue/chondrocyte injury
    - Repeated corticosteroid injections, over a long span, can at least theoretically lead to suppression of the body's own steroid production
  - Generally not recommended > 3-4x/year
    - Weigh injection benefit vs. potential risk
- **HA preparations: Basic principles**
  - Mechanism of action: Role of HA in synovial fluid
    - Maintain viscoelastic structural and functional properties of articular matrix
    - Likely multifactorial, including improving viscoelastic structural and function properties of synovial fluid and improved cartilage matrix stability
  - Proposed mechanisms of action of exogenous HA
    - Antiinflammatory, nociceptive, &/or stimulation of in vivo HA synthesis
  - Multiple HA preparation injections generally needed
- **Differences between HA products**
  - Commercially available HAs have various molecular weight, viscosities, resident times in joint, etc.
    - No literature to date supports substantial clinical differences based on these distinctions
  - Literature supports pain relief best at 5-13 weeks
  - Some pain/function improvements up to 26-52 weeks
- **HA and corticosteroid comparison**
  - HAs more expensive than corticosteroids
  - HA onset of action much slower than corticosteroid
    - 1 study suggests synergistic effect of combination HA/steroid
    - Duration of action may be longer than corticosteroids
  - HAs may cause inflammatory response, especially with inadvertent extraarticular injection
- **Indications for HA products**
  - FDA approval only for osteoarthritis of knee

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Utilize standard joint access techniques, whenever possible
  - Mark site, center fluoroscopy beam at entry site to avoid distortion/parallax
  - Severe osteoarthritis may limit standard approach
    - Osteophytes may block joint entry
    - Change needle entry site, if necessary, to avoid osteophytes and successfully enter joint
    - Can gently "walk" small-gauge needle around osteophytes and into joint

Procedure Steps

- Standard sterile technique
- Use gadolinium or air for contrast agent if patient allergic to iodinated contrast agents
- If contrast does not flow into joint, adjust needle (try each adjustment separately)
  - Confirm needle tip on bone, not dense scar or other adjacent soft tissues
  - Ensure needle is not buried in bone (may need to pull back very slightly and perform test injection)
  - Turn needle bevel
  - Withdraw needle 1-2 cm and angle slightly to adjacent portion of joint
  - If repeated attempts continue to be unsuccessful, may need to remove needle and restart procedure with new target site
- Obtain image after injection of small amount of contrast, showing contrast flow away from needle and into joint spaces
  - Contrast should **not** pool at needle tip
- Obtain additional image after therapeutic agent injected
  - Dispersal and dilution of contrast confirms intraarticular injection of therapeutic agent
- Document variant joint communication
  - e.g., ankle communicating with subtalar joint, hip joint communicating with iliopsoas bursa, etc.
  - May limit ability to distinguish source of pain relief when this is present

Findings and Reporting

- Report level of pain before and after injection (0-10 scale)
  - May be reported as pain with rest or with provocative maneuvers (should be consistent for both preprocedure and postprocedure assessment)

Alternative Procedures/Therapies

- Radiologic
  - Can use either fluoroscopy or ultrasound for guidance
    - Ultrasound guidance provides added benefits of real-time visualization, particularly useful when carefully navigating around neurovascular structures
      - Can also directly visualize joint effusion to target
      - Usefulness is dependent on patient body habitus and user experience

OUTCOMES

Problems

- Hyperglycemia in diabetic patients with corticosteroid intraarticular injections
  - Advise patient to monitor glucose level frequently for 72 hours following procedure
- Facial flushing with corticosteroid injections
- Small risk of inflammatory response with HA preparations (2-3%)
- Skin discoloration/atrophy
  - More common when injecting more superficial joints
  - Use more soluble agent (such as dexamethasone) for superficial injections to decrease risk
- Allergic reaction (uncommon)
- Lack of pain relief
- Postinjection pain flare
  - Has been reported with corticosteroids, for a few days following procedure

Complications

- Most feared complication(s)
  - Infection (1:30,000 incidence)
- Other complications
  - Temporary paresthesias or muscle weakness
    - Due to local anesthetic (avoid path of nerves during injection)
    - Caution patients, assist patient from table to prevent falls
      - Also potentially from vasovagal response
  - Chondrocyte damage a potential risk
    - Has been reported in vitro from anesthetics
      - Some reports claim ropivacaine safer than bupivacaine

Expected Outcomes

- Initial symptomatic relief from local anesthetic
  - Several hours' duration
- Variable onset of response to steroid preparation
  - 2-5 days on average, may take up to 10 days
- Variable duration of corticosteroid response
  - Typically 2-6 months
- Variable response to HA supplements
  - Slow onset, maximum benefit at 4-6 weeks
  - Variable duration, up to 6 months

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Common Injectable Corticosteroids

	Strength	Relative Potency*	Recommended Dose: Small	Recommended Dose: Intermediate	Recommended Dose: Large	Fluorinated
Most Soluble						
Betamethasone sodium phosphate (Celestone Phosphate)	3 mg/mL	25		1.5-3.0 mg	6-12 mg	Yes
Soluble						
Dexamethasone sodium phosphate (Decadron)	4 mg/mL	25		2-4 mg	7.5-15.0 mg	Yes
Prednisone sodium phosphate (Hydeltrasol)	20 mg/mL	4	5-10 mg	12.5-25.0 mg	50-100 mg	No
Slightly Soluble						
Methylprednisolone acetate (Depo-Medrol)	20/40/80 mg/mL	5	2.5-5.0 mg	10-20 mg	40-80 mg	No
Triamcinolone diacetate (Arisopspan Forte)	25/40 mg/mL	5	2.5-5.0 mg	10-20 mg	40-80 mg	Yes
Prednisolone tebutate (Hydeltra-TbA)	20 mg/mL	4	5-10 mg	12.5-25.0 mg	40-80 mg	No
Relatively Soluble						
Triamcinolone acetonide (Kenalog)	10/40 mg/mL	5	2.5-5.0 mg	10-20 mg	40-80 mg	Yes
Triamcinolone hexacetonide (Aristospan)	20 mg/mL	5	2.5-5.0 mg	10-20 mg	40-80 mg	Yes
Hydrocortisone acetate (Hydrocortone)	25 mg/mL	1	2.5-5.0 mg	10-20 mg	40-80 mg	Yes
Dexamethasone acetate (Decadron-LA)	8 mg/mL	25		2-4	7.5-15.0 mg	Yes
Combination						
Betamethasone sodium phosphate betamethasone acetate (Celestone Soluspan)	6 mg/mL	25		1.5-3.0 mg	6-12 mg	Yes

**Corticosteroid potency is relative, and hydrocortisone is arbitrarily assigned a value of 1. Adapted from Skedros JG et al: BMC Musculoskeletal Disorders. 8:63, 2007.*

Joint Classification

Small Joint	Intermediate Joint	Large Joint
Fingers	Acromioclavicular joint	Hip
Toes	Elbow	Knee
Tarsometatarsal joints	Wrist	Glenohumeral joint
Intertarsal joints	Temporomandibular joint	Subacromial joint
	Ankle	

Adapted from Current Procedural Terminology (CPT) 2004. American Medical Association: AMA Press.

Viscosupplementation Products

	Euflexxa	Hyalgan	Orthovisc	Supartz	Synvisc
Number of injections	3	5	3-4	5	3 or 1 (SynviscOne)

**Healthy human hyaluronic acid molecular weight = 5,000 kDa.*

Ultrasound-Guided Musculoskeletal Procedures

KEY FACTS

PREPROCEDURE

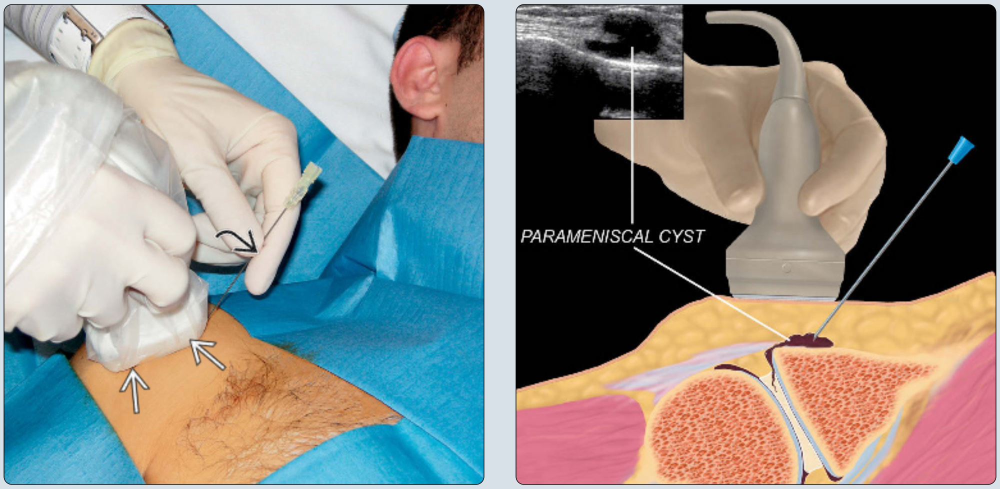
- Alternate method of guidance for needle placement
- Advantages
  - Ideal modality when targeting soft tissue structures, such as bursa or tendon sheath
  - Allows real-time visualization of needle throughout procedure
  - Allows visualization of soft tissue structures to target (effusion, tenosynovitis) and avoid (neurovascular structures)
  - Allows for nonstandard patient positioning in challenging cases or in patients with limited mobility

PROCEDURE

- Use high-frequency US probe unless deep target or large body habitus
- Long flat head linear array probe best for tracking needle course
- Perform preliminary US for planning
  - Determine location of blood vessels
  - Evaluate target and optimal skin entry site
- Detailed understanding of anatomy needed to accurately localize small joints and tendon sheaths
- US allows flexibility in choosing needle approach
- Position needle; insert along long axis of probe at angle to allow visualization
  - Needle more easily seen if fairly horizontal course
- Visualize needle tip when positioning in joint or desired compartment
- Aspirate/inject fluid via needle using real-time US
  - Confirm volume change in compartment

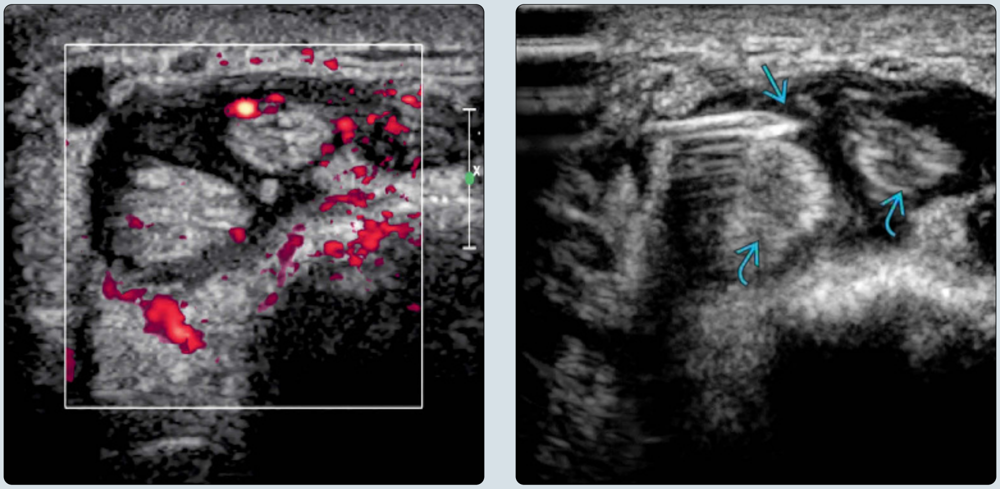
OUTCOMES

- Pain relief with therapeutic injection
- Diagnostic information with diagnostic aspiration
- Potential complications
  - Infection (rare)
    - Careful sterile technique must be used


Ultrasound Long-Axis Technique

Ultrasound Long-Axis Technique

(Left) *Photograph shows the method for US guidance for needle placement. The needle* ➙ *is introduced at an angle, along the long axis of the US probe* ➡, *for optimal visualization. Of note, a short-axis technique may sometimes also be employed, although only the needle tip would be seen in that case.* **(Right)** *Graphic shows positioning of probe and needle for ultrasound-guided procedures via long-axis technique. The needle is shown at a 45° angle; further reducing the angle to 30° will improve needle visualization.*


1st Extensor Compartment Tenosynovitis

1st Extensor Compartment Injection

(Left) *Power Doppler US demonstrates thickening of the tendon sheath of the 1st extensor compartment, along with hyperemia, consistent with advanced tenosynovitis.* **(Right)** *US in the same patient demonstrates needle placement for steroid injection in the 1st extensor compartment. Note careful positioning of the needle tip* → *in the tendon sheath but carefully avoiding the tendons* ➙.

TERMINOLOGY

Definitions

- **US guidance**
  - US provides alternate modality for image guidance when performing procedures
  - Allows direct visualization of needle and soft tissue structures, real time, during procedure

PREPROCEDURE

Indications

- Ideal modality when targeting soft tissue structures, such as bursal or tendon sheath therapeutic injections
- Also useful for aspirations of periarticular collections, or potentially joint aspiration, when effusion is known and can be directly visualized with US
- May occasionally be used for arthrographic injection, prior to CT/MR arthrogram, mainly in patients with iodinated contrast allergy

Getting Started

- Things to check
  - Preliminary US of area for planning
    - Identify any abnormalities (joint effusion, periarticular collection, bursal or tendon sheath fluid, etc.) that may be targeted for aspiration/injection
    - Note presence of any surrounding neurovascular structures, for avoidance during procedure
    - Mark optimal skin entry site and probe position
- Equipment list
  - Standard procedure tray, anesthetics, needles, etc.
  - US probe with sterile cover and sterile gel
  - Syringes and specimen tubes as needed

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Position patient so that operator can hold probe in one hand and needle in other while viewing monitor
    - Alternatively, may have US technologist assist by holding probe, allowing physician to have both hands free for procedure
  - Position tray close to hand holding needle for easy transfer
  - US allows flexibility in choosing nonstandard needle approach
    - Often easier than fluoroscopy in patients with difficult anatomy or who are difficult to position

Procedure Steps

- Determine optimal US probe
  - Medium- to high-frequency probes generally utilized, unless targeting deep structure or in patients with large body habitus
  - "Hockey-stick" probe works very well for smaller areas of the body, particularly in wrist/hand and ankle/feet
- Detailed understanding of anatomy needed to accurately localize small joints and tendon sheaths
  - When injecting steroids into tendon sheaths, it is critical to place needle within tendon sheath, rather than in tendon itself
- Standard sterile technique
- Sterile probe and sterile gel is utilized, reproducing image acquired during planning
- Position needle; insert along long axis of probe to allow visualization
  - Flatter needle course is more easily seen
  - Helpful maneuvers for locating needle tip
    - Wiggle needle slightly; observe in real time
    - Hydrodissection: Injection of anesthetic, observe dissection of tissue planes, to localize tip
    - "Heel-toe maneuver": Press down with portion of probe furthest from needle tip, to flatten angle between probe and tip
- Visualize needle tip in joint or desired compartment, prior to any injection
- Aspirate/inject fluid via needle using real-time US
  - Confirm volume change in compartment
  - For tendon sheath or bursal injections, injectate should flow freely within appropriate compartment

Findings and Reporting

- Pertinent preprocedural findings
- Quality/color of fluid aspirated
- Degree of pain relief after therapeutic injection

POST PROCEDURE

Post Procedure Imaging

- Document location of injectate after injection
- Document any residual fluid present after aspiration

OUTCOMES

Complications

- Most feared complication(s)
  - Infection (rare)
    - Careful sterile technique must be used
    - Never pass needle through suspected skin/superficial soft tissue infection
- Other complications
  - Injury to adjacent structures
    - Critical to visualize and avoid neurovascular structures during procedure

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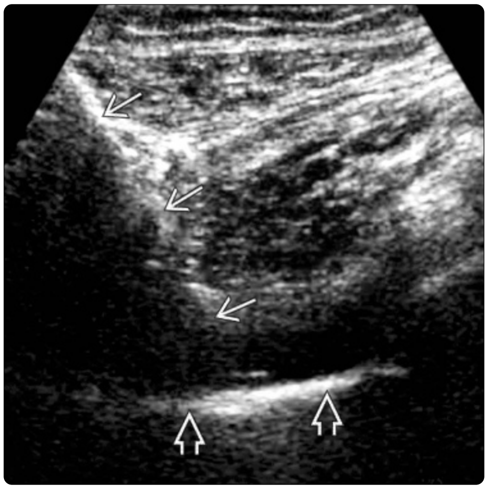
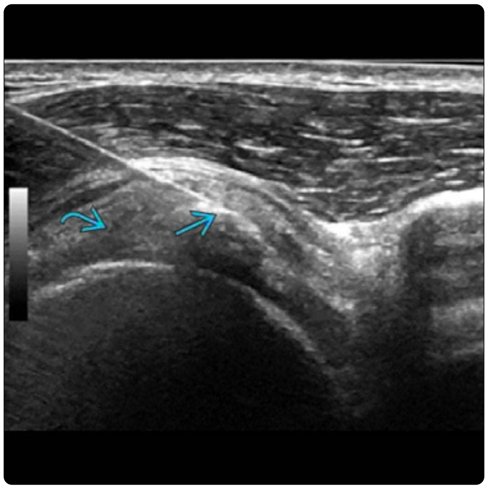
(Left) *US shows guidance for needle placement during aspiration of a hip effusion. The needle → can be visualized in real time, along its course to the target, in this case the femoral neck ⇨.* **(Right)** *US shows placement of an 18-gauge needle within calcifications → in the supraspinatus tendon ↪, consistent with hydroxyapatite deposition disease. Calcifications are curvilinear and shadowing and are repeatedly fenestrated and pulsated with this treatment method.*

Aspiration of Hip Joint Effusion

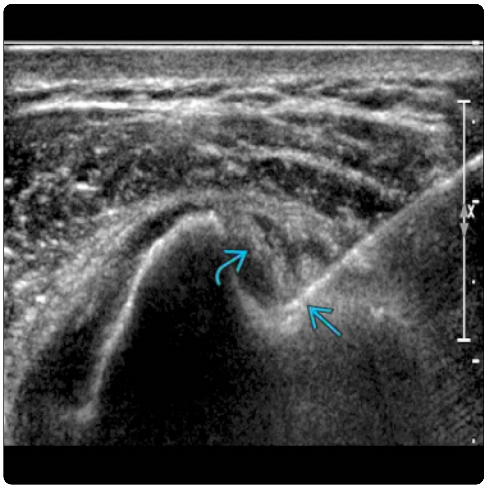


Rotator Cuff Calcific Lavage

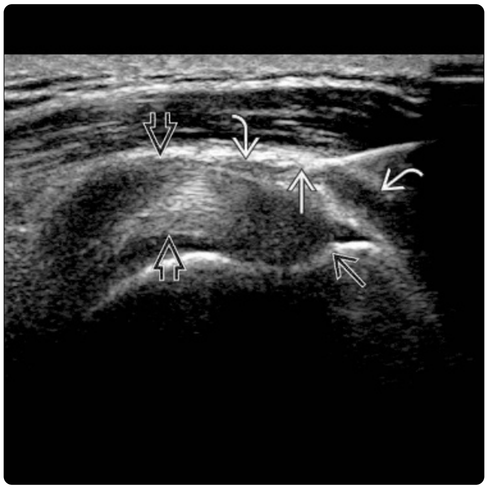


(Left) *US shows careful needle tip → placement within the biceps tendon sheath, avoiding the biceps tendon ↪, for therapeutic steroid injection.* **(Right)** *US shows therapeutic injection of anesthetic and steroid into the subacromial-subdeltoid bursa. The needle tip → is in the bursa ↪. The supraspinatus tendon ⇨ is seen inserting on the greater tuberosity ⇨. Care should be taken to inject steroid into the bursa rather than the actual tendon.*

Biceps Tendon Sheath Injection

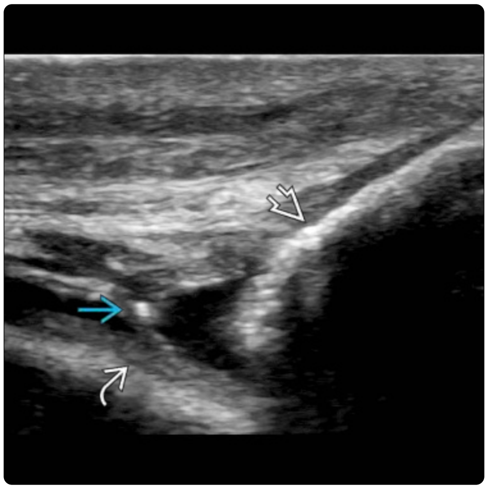


Subacromial Bursa Injection

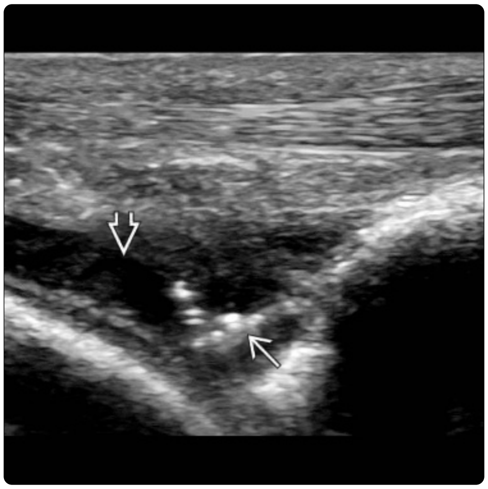


(Left) *US was performed with the patient supine using an anterior needle approach. The distal tibia ⇨ and talar dome ↪ are distinctive landmarks. The echogenic 25-gauge needle tip → is visible in the ankle joint.* **(Right)** *US in the same patient during corticosteroid injection shows echogenic steroid → in the joint, along with an increased volume of ankle joint fluid ⇨ now seen.*

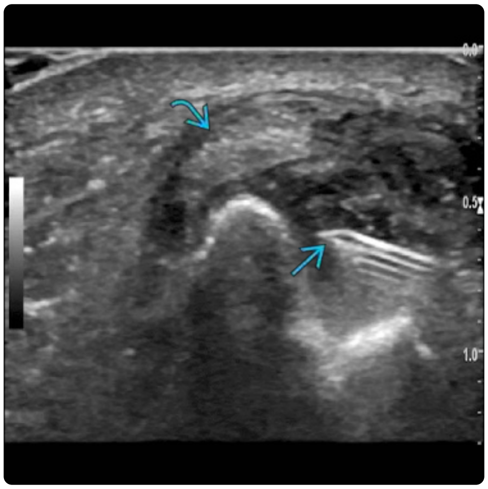
Ankle Joint Injection



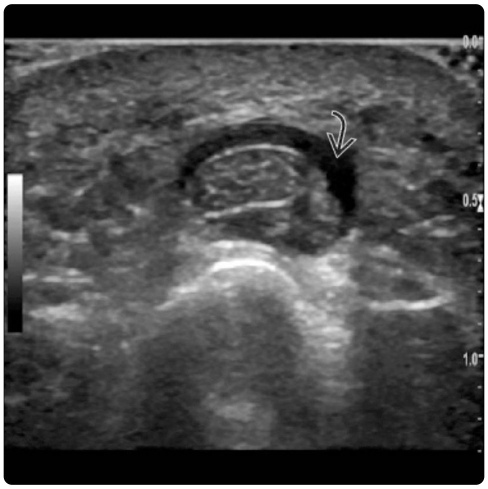
Ankle Joint Injection



Extensor Carpi Ulnaris Tendon Sheath Injection

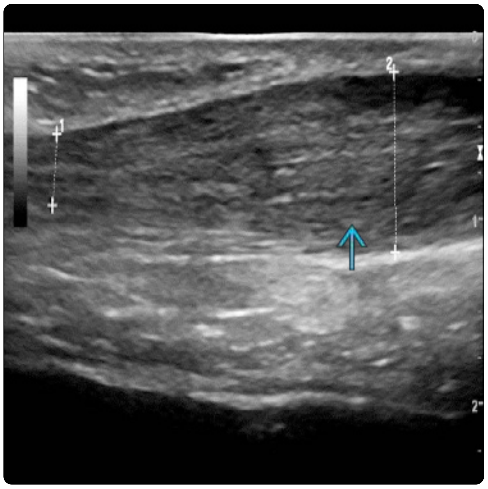


Extensor Carpi Ulnaris Tendon Sheath Injection

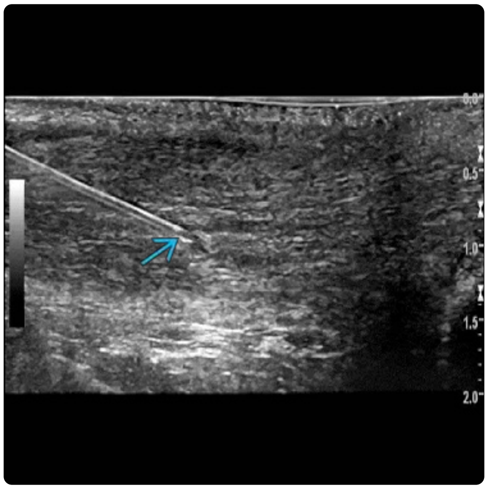


(Left) *US demonstrates placement of the needle tip ⇨ in the 6th extensor compartment, adjacent to the extensor carpi ulnaris tendon ↷, for therapeutic steroid injection.* **(Right)** *US in the same patient after injection demonstrates injectate ↷ flowing freely within the extensor carpi ulnaris tendon sheath, visualized more proximally in this image.*

Achilles Tendinosis

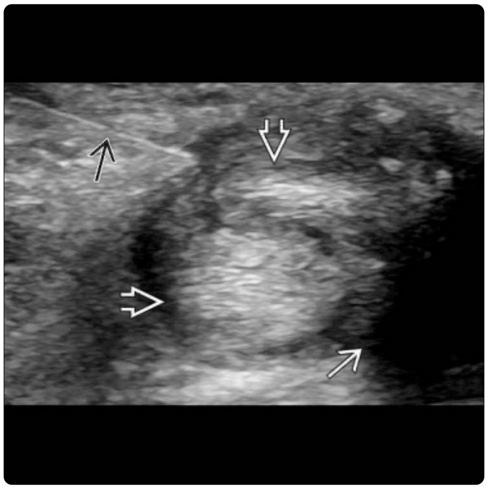


Achilles Tendon Platelet-Rich Plasma Treatment

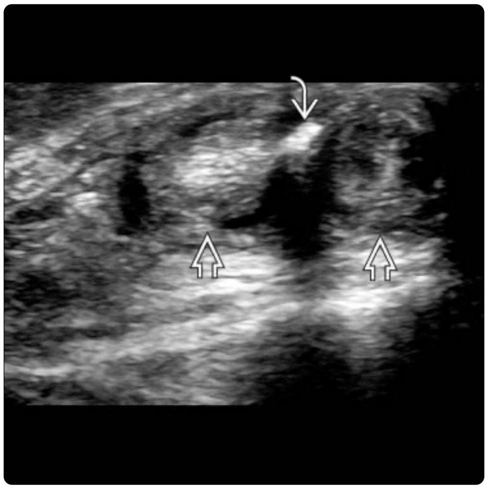


(Left) *Preprocedural US demonstrates Achilles tendinosis, with fusiform thickening of the Achilles tendon ⇨, up to ~ 1 cm. The Achilles should normally be ≤ 6 mm in AP thickness.* **(Right)** *US in the same patient during platelet-rich plasma treatment is shown. This is a rare example when the needle tip ⇨ is purposely placed within the tendon, in this case, for treatment of underlying tendinosis and refractory pain with platelet-rich plasma therapy.*

Peroneal Tendon Sheath Injection



Peroneal Tendon Sheath Injection



(Left) *US obtained along the lateral aspect of the hindfoot shows the placement of a 25-gauge needle → for a peroneal tendon sheath injection. The peroneal tendons ⇨ are seen in short axis and are highly echogenic. Native fluid ➡ is seen in the tendon sheath in this patient with tenosynovitis.* **(Right)** *US in the same patient after needle removal shows echogenic material ↷ in the tendon sheath, representing the injected corticosteroid. The peroneal tendons ⇨ are slightly separated due to the volume of injectate.*

KEY FACTS

PREPROCEDURE

- Indications
  - Suspected injury to labrum, ligaments, or capsule
  - Slightly improved sensitivity in diagnosing small, partial-thickness rotator cuff injury/tear compared to standard MR

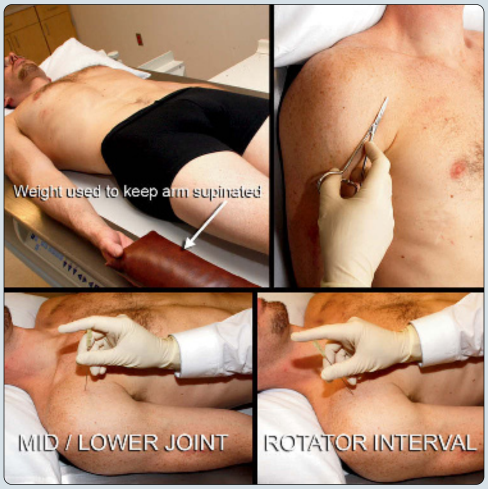
PROCEDURE

- Anterior approaches most commonly utilized, via either rotator interval approach or mid joint approach (Schneider technique)
- Posterior approach: Rarely utilized with fluoroscopy; may be employed in cases with anterior pain, depending on operator preference
- Contrast should flow away from needle tip
  - Contrast pooling at needle tip indicates malpositioned needle
- Problems
  - Joint capsule often quite firm; may be mistaken by inexperienced operator for bone, leading to extraarticular injection
  - Contrast injection in labrum, ligaments, or surrounding muscles may mimic injury
  - Injection of rotator interval itself can obscure pathology at this site

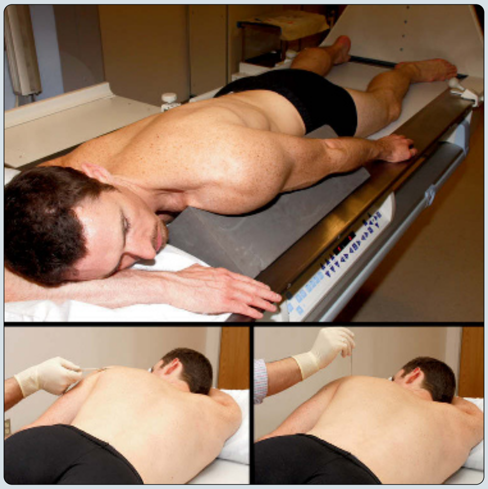
POST PROCEDURE

- Postarthrogram MR should include imaging in 3 planes (axial/coronal/sagittal)
  - Fluid-sensitive sequences, as on routine shoulder MR protocol, are useful in assessing for edema/tears
  - T1 fat-saturated sequence can also be helpful in distinguishing contrast from fluid
  - Include T1 non-fat-saturated sequence, primarily for anatomy and to assess for fatty atrophy of muscles

Patient Positioning

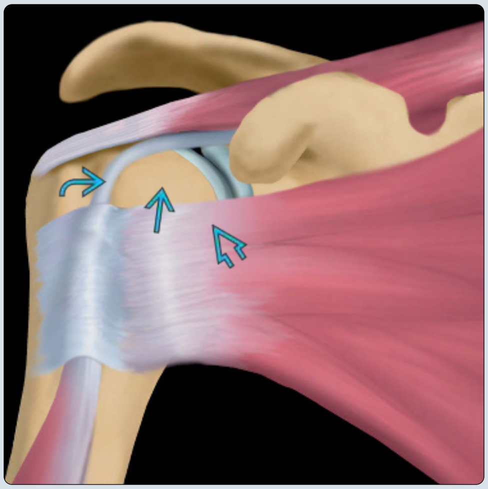


Patient Positioning, Posterior Approach

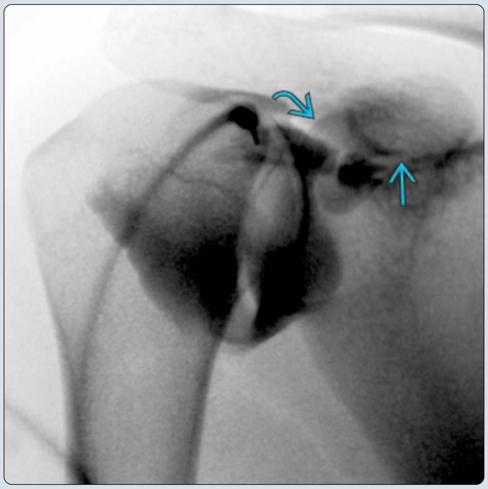


(Left) *Clinical photo shows a supine patient with arm externally rotated. Two possible entry sites are shown, in the mid joint and the rotator interval. A mid joint injection traverses the subscapularis and can cause increased pain.* **(Right)** *Clinical photo shows patient positioned prone for a posterior approach with affected shoulder elevated on wedge and arm externally rotated. The entry site in this location should be over superomedial humeral head.*

Rotator Interval Anatomy Drawing



Rotator Interval Approach



(Left) *Graphic of the rotator interval demonstrates the corresponding anatomical considerations. An ideal target site* → *lies above the subscapularis* → *and below the biceps tendons* →*.* **(Right)** *Rotator interval approach injection demonstrates ideal location of needle tip. The tip should be superior to the inferior edge of the coracoid process* → *and below the superior glenoid rim* → *to avoid the subscapularis and biceps tendons, respectively.*

PREPROCEDURE

Indications

- Suspected injury to labrum or surrounding ligaments
- Suspected rotator cuff injury/tear (RCT)
  - MR arthrography only slightly more accurate than standard MR, mainly for partial-thickness tears

Getting Started

- Injection of 12-15 mL will distend glenohumeral joint
- 22-g needle (either 1.5'' or 3.5'', depending on patient size) works best

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Anterior approach is by far most common, either via rotator interval or mid joint approach (Schneider technique)
- **Anterior approach** (supine position)
  - Rotate arm externally, place weight on palm to hold position
  - Several possible entry points
    - Rotator interval: Superomedial portion of humeral head
      - ☐ Space formed by subscapularis (below), supraspinatus (above), and surrounding ligamentous structures
      - ☐ Ideal target is a few mm lateral to humeral cortex, superomedial quadrant, above base of coracoid process and below superior rim of glenoid
    - Mid joint: Mid to inferior portion of humeral head, just lateral to glenoid
  - Rotator interval approach preferred by many, as it avoids traversing subscapularis, and has been shown to reduce patient discomfort and fluoroscopy time, and also have less misplaced injections
- **Posterior approach** (prone or semiprone position)
  - Elevate shoulder with wedge/towels
  - Rotate arm externally
  - 2 useful entry points
    - High: Superomedial humeral head
    - Low: Inferomedial aspect humeral head
      - ☐ Higher risk of extracapsular injection
  - Rarely performed with fluoroscopy; may be used with anterior pain to avoid obscuring anterior structures at time of injection
    - More commonly performed with ultrasound guidance, or clinically, without imaging guidance

Procedure Steps

- Position patient for desired approach
- Sterilely prepare/drape skin
- Keep needle perpendicular to table and fluoroscopy beam at chosen entry site
- Advance needle to humeral head (needle tip on bone)
- Under intermittent fluoroscopy inject contrast
  - Should flow freely (low resistance) within joint space
  - Pooling at needle tip indicates extraarticular injection

POST PROCEDURE

Post Procedure Imaging

- MR
  - T1-weighted sequences
    - Axial without fat saturation: Evaluates bony Bankart and cartilage injuries
    - Oblique coronal with fat saturation: Helpful in distinguishing contrast from fluid
    - Sagittal without fat saturation: Useful for assessing for rotator cuff muscle atrophy
  - T2-weighted or PD with fat-saturation sequence
    - Oblique coronal
    - Oblique sagittal
  - Abduction, external rotation (ABER)
    - Particularly useful in assessing for anteroinferior labral tears in setting of shoulder instability
- CT: MDCT with multiplanar reformations
  - Employ oblique coronal and sagittal to correspond to standard MR planes
  - Generally performed in patients with contraindication to MR (relative or absolute)

OUTCOMES

Problems

- Extraarticular injection: Contrast does not outline joint, but puddles around needle tip or dissects in muscle planes
  - May mimic findings of tear on MR
- Injection of rotator interval
  - May obscure rotator interval pathology
- Injection of subacromial/subdeltoid bursa
  - May lead to diagnostic dilemma when attempting to diagnose full-thickness rotator cuff tear on MR, as intraarticular contrast normally should not enter this bursa with intact rotator cuff

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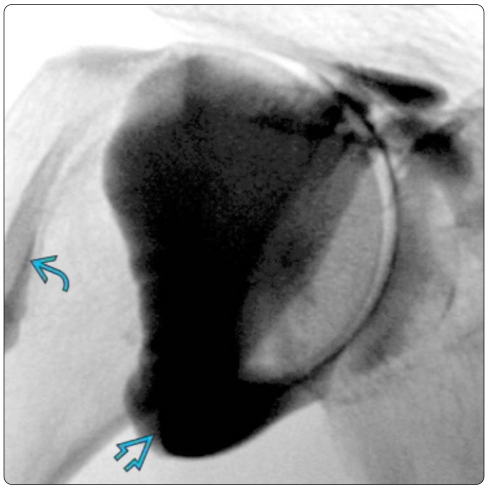
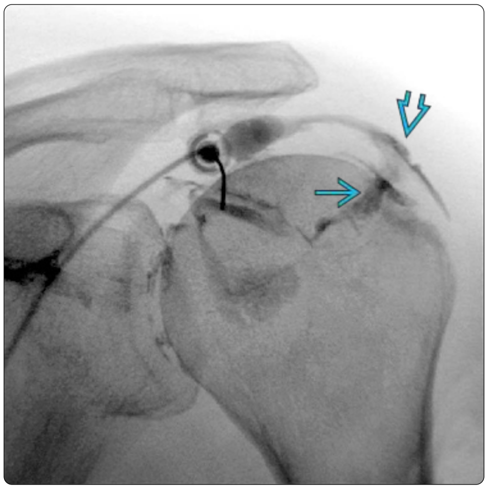
(Left) *Anteroposterior arthrogram shows optimal joint distention with filling of both the axillary recess ⇨ and the biceps tendon sheath ↪. The glenohumeral joint usually is filled by about 12-15 mL of injected fluid.* **(Right)** *Contrast injection via rotator interval approach demonstrates a full-thickness rotator cuff defect → with contrast filling the subacromial/subdeltoid bursa ⇨. This is indicative of a full-thickness rotator cuff tear (RCT).*

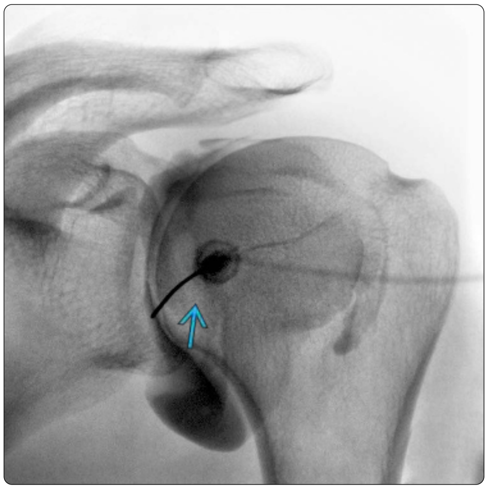


Conventional Shoulder Arthrogram (Ideal Glenohumeral Joint Distention)

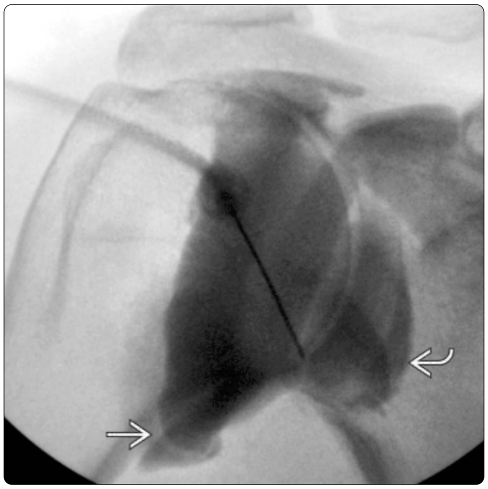


Injection Demonstrating Full-Thickness Rotator Cuff Tear

(Left) *Anterior shoulder injection via mid joint approach is shown. Needle tip traverses the subscapularis tendon, as demonstrated on prior graphic. Needle tip with this technique could also be directed just lateral to this, overlying the humeral head →.* **(Right)** *AP arthrogram shows low anterior approach with needle partly intraarticular and partly intracapsular. Extravasation is evident along humeral neck ➡ and glenoid ↪. This technique can be painful for patients and should be avoided.*

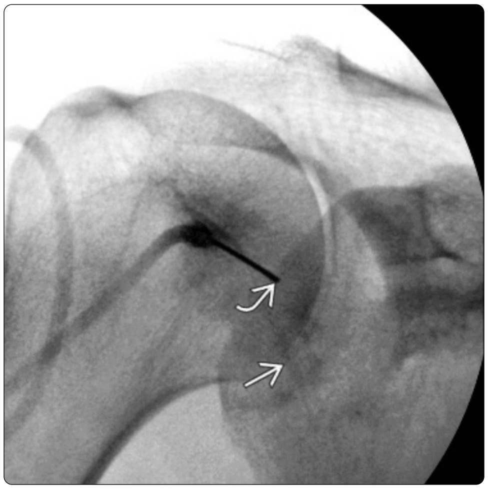


Mid Joint (Schneider) Approach

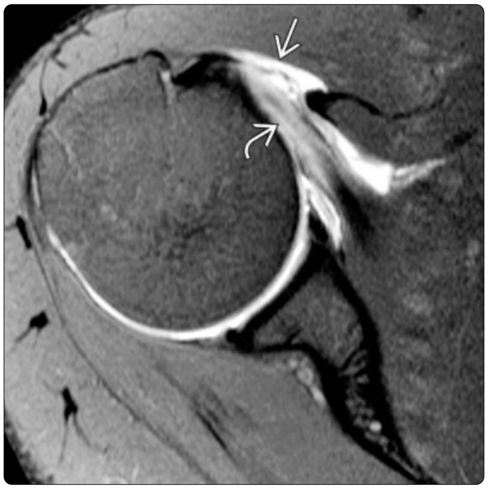


Low Anterior Approach

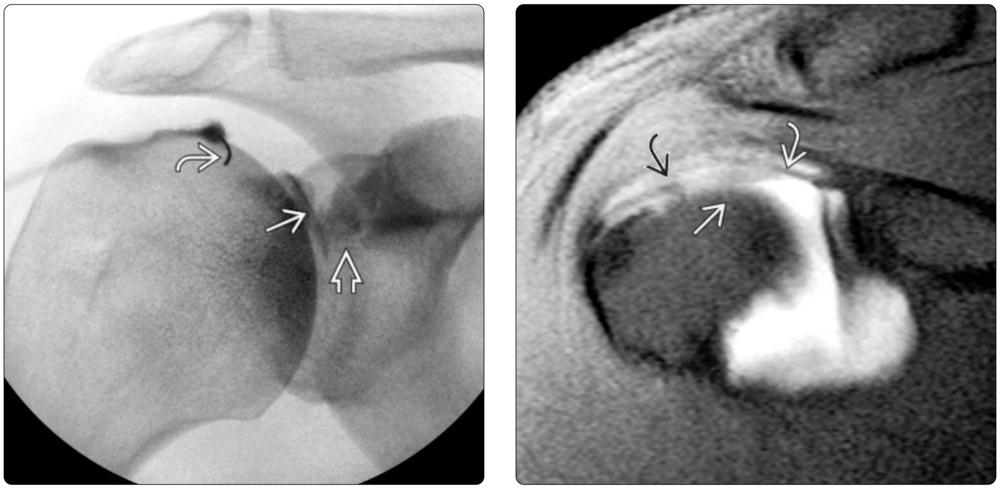
(Left) *Shoulder arthrogram shows anterior mid joint approach with the needle tip ↪ at the midhumeral head. Faint, streaky contrast ➡ overlying the joint suggests a partially extraarticular location.* **(Right)** *Axial T1WI FS MR arthrogram in the same patient confirms a mixed injection with contrast in subscapularis tendon ↪ as well as anterior ➡ to the joint. This could mimic findings of a tear; in this case, the subscapularis was intact on arthroscopy. Resistance to injection should prompt needle repositioning.*



Mid Joint Approach (Initial Arthroscopic Image)



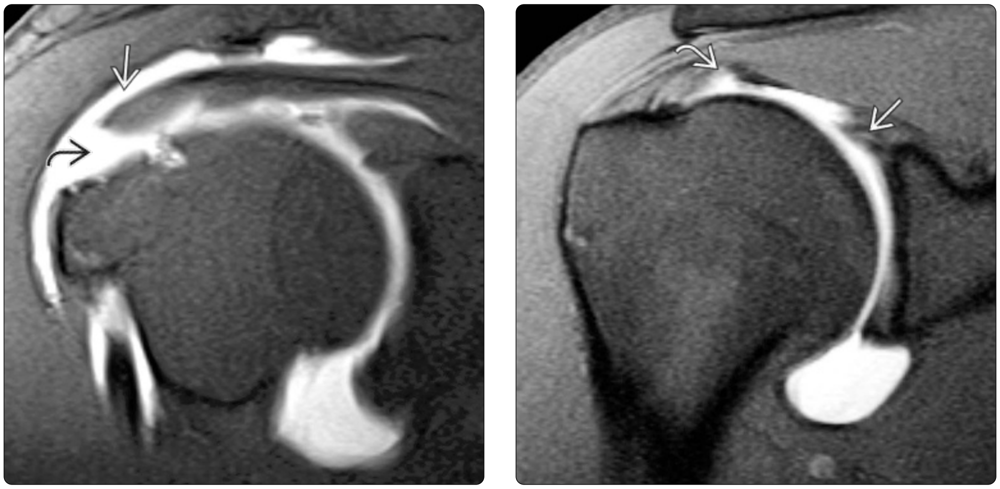
Mid Joint Approach



Posterior Arthrography Approach (Early Glenohumeral Joint Filling)

Rotator Interval Approach

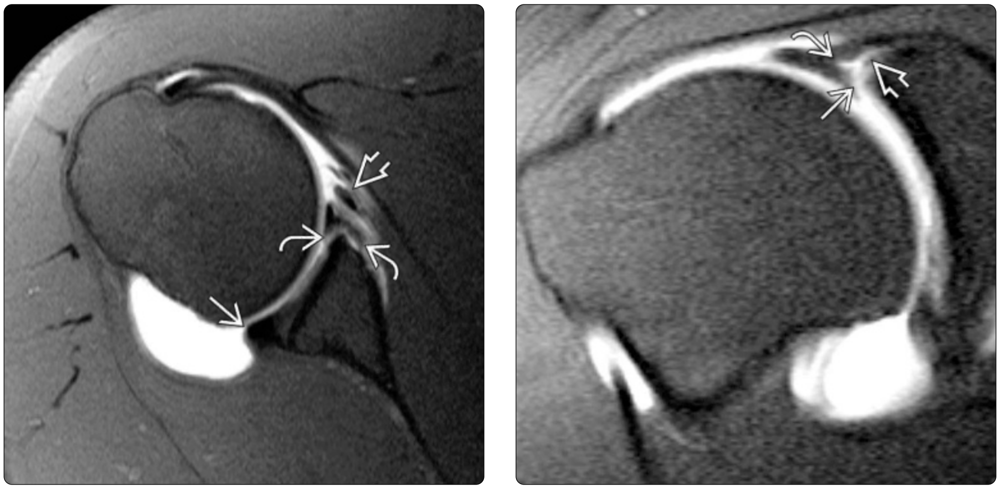
(Left) *Shoulder arthrogram shows a needle ↪ introduced into glenohumeral joint via posterior approach. Contrast medium → is flowing freely away from needle into the joint. Since the subscapularis bursa ⇨ is dependent in prone position, it fills early during injection.* **(Right)** *Coronal oblique T1WI FS MR arthrogram obtained following posterior approach shows where needle was placed →. This is adjacent to the superior glenohumeral ↪ and coracohumeral ligaments ⤻, which form the biceps sling.*



Full-Thickness Rotator Cuff Tear

Partial-Thickness Rotator Cuff Tear

(Left) *Coronal T1WI FS MR arthrogram shows a full-thickness tear of the supraspinatus tendon. Contrast extends through the tear ⤻ and into the subacromial/subdeltoid bursa →.* **(Right)** *Coronal T1WI FS MR arthrogram in a baseball pitcher shows a small, partial-thickness tear along undersurface of infraspinatus ↪. Small, partial-thickness tears are better seen on MR arthrography than on noncontrast MR. An associated posterosuperior labral tear → was better seen on axial images.*



Anterior Labral Tear

Superior Labral SLAP Tear

(Left) *Axial MR arthrogram shows anterior labral detachment ↪. A normal middle glenohumeral ligament ⇨ is seen anterior to the torn labrum. The posterior labrum → is intact.* **(Right)** *Coronal MR arthrogram shows contrast extending between superior labrum and glenoid →. This can occur with either variant labral anatomy or SLAP tear (superior labral tear from anterior to posterior). Contrast extending into substance of superior labrum ↪ and beneath biceps anchor ⇨ are reliable signs of SLAP tear.*

Elbow Arthrography

KEY FACTS

PREPROCEDURE

- Indications
  - Collateral ligament injury, osteochondral injury, loose body
  - Therapeutic injection
    - Anesthetic &/or corticosteroid
  - Aspiration for suspected infection
- Contraindications
  - Overlying soft tissue infection

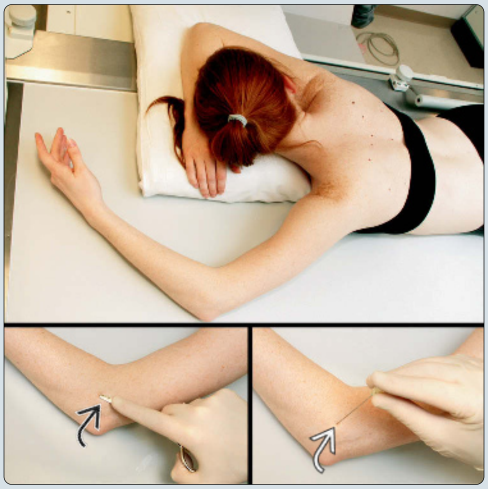
PROCEDURE

- Patient position
  - Patient prone, head turned to side
  - Arm over head, elbow bent, thumb up
- Localize injection site
  - Between capitellum and radial head
  - Alternate: Posterior transtriceps approach
- Administer local anesthesia with 25-gauge needle
- Advance same needle into joint
  - Joint is quite superficial even in obese patients
- Inject contrast while fluoroscopically monitoring
  - Confirm anterior/posterior recesses well distended
  - Injection volume: 5-8 mL
- Obtain postprocedure fluoroscopy spot images
  - For diagnostic examination, obtain MR or CT

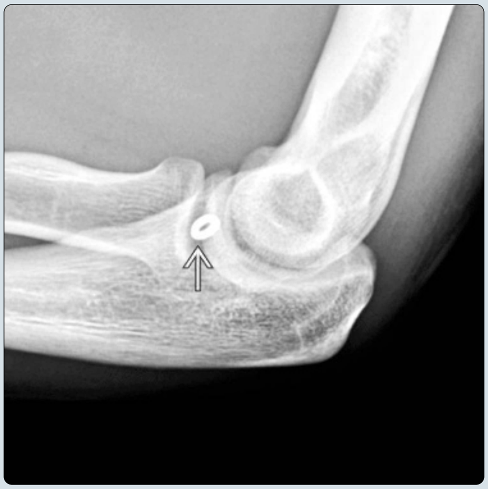
OUTCOMES

- Problems
  - Contrast extravasation laterally from superficial needle position may mimic ligament tear
  - Infection is rare complication

Elbow Arthrography: Lateral Approach (Puncture Site)

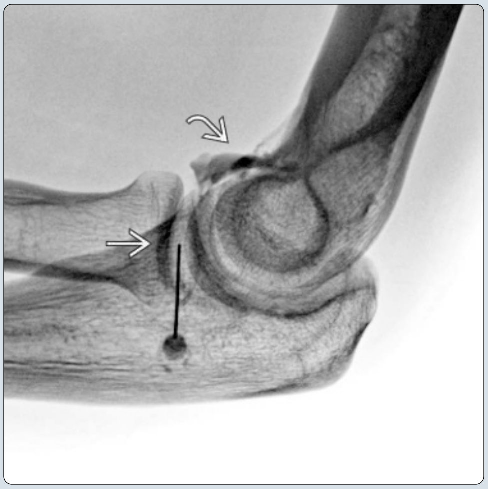


Elbow Arthrography: Lateral Approach (Puncture Site)

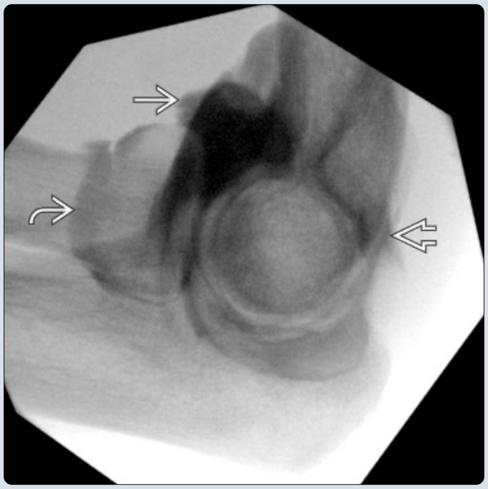


(Left) *Photograph shows elbow arthrogram positioning: Prone, arm over the head, elbow bent, and thumb up. The space between the capitellum and radial head is localized ↪, and a 25-gauge short needle ↪ is advanced into the joint.* **(Right)** *Lateral radiograph shows a radiopaque marker → taped to the skin for joint localization. By using this technique, the marker will not move between fluoroscopy and the placement of an indelible ink mark at the site.*

Elbow Arthrography: Lateral Approach (Fluoroscopic Imaging)



Elbow Arthrography: Lateral Approach (Fluoroscopic Imaging)



(Left) *Lateral elbow arthrogram shows the ideal position of the needle, adjacent to the center of the radial fovea →. Contrast typically fills the coronoid fossa ↪ prior to filling posteriorly.* **(Right)** *Lateral elbow arthrogram shows full distention of the joint, with contrast extending into the coronoid → and olecranon ⇨ fossae and also filling the radial recess ↪.*

PREPROCEDURE

Indications

- Collateral ligament injury, osteochondral injury, loose body
- Therapeutic injection: Anesthetic &/or corticosteroid
- Suspected infection

Contraindications

- Overlying soft tissue infection

Getting Started

- Things to check
  - Medical history: Bleeding risk, medication list
  - Allergies: For iodinated contrast allergy, either premedication can be administered, or exam can be performed under ultrasound guidance
  - Laboratory parameters: Most recent INR (if patient is on warfarin); should be in therapeutic range
  - Verify written, informed consent
  - Coordinate with MR staff (if MR arthrogram)
    - Generally, MR should be completed within hour of injection
- Medications
  - 1% lidocaine for local anesthetic
    - May buffer 1:9 with sodium bicarbonate (optional)
  - Nonionic iodinated contrast
  - Gadolinium-based contrast (dilute 1:200)
  - Contrast mixture for MR arthrography: 5-mL nonionic iodinated contrast, 5-mL normal saline, and 0.05-mL gadolinium
  - Contrast mixture for CT arthrography: 5-mL nonionic iodinated contrast and 5-mL normal saline
- Equipment list
  - Standard arthrogram tray
    - Sterile, fenestrated drape
    - Local antiseptic solution
    - 18-gauge and 25-gauge 1.5" needles
    - 1-mL, 5-mL, and 10-mL syringes
    - Sterile tubing
  - Guidance equipment (fluoroscope, ultrasound)
  - Positioning aids (pillows, towels, wedges, etc.)
  - Skin localizer: BB on piece of tape or other marker
  - Indelible marker to mark skin

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Lateral approach
    - Patient prone on fluoroscopy table with arm over head and elbow flexed 90°; rotate forearm so that ulna is on fluoroscopy table and thumb is pointed up
    - Should look like lateral elbow radiograph with radiocapitellar joint clearly visible

Equipment Preparation

- Prepare contrast solution and attach contrast-filled syringe to flush tubing and flush with contrast, ensuring there are no air bubbles

Procedure Steps

- **Lateral approach: Radiocapitellar access**
- Position patient and prepare injection site
  - Localize radiocapitellar joint space fluoroscopically, and mark overlying skin with indelible marker
  - Using sterile technique, prep and drape injection site
- Access joint and perform contrast injection
  - Administer local anesthesia with 1% lidocaine using 25-gauge 1.5" needle
  - Detach syringe containing lidocaine while keeping needle used for local anesthetic in patient
  - With fluoroscopic guidance, guide anesthesia needle into radiocapitellar joint; should feel needle drop into joint
  - Connect contrast-filled syringe and flush tubing to needle
  - Inject very small amount of contrast while observing fluoroscopically
    - Should see contrast flowing away from needle; if contrast pools around needle tip, then needle is not intraarticular and must be repositioned
  - Once intraarticular positioning of needle is confirmed, perform contrast injection
    - Injection volume: 5-8 mL
  - Remove needle, cleanse skin, and place bandage
- Obtain spot fluoroscopic views (AP, lateral, oblique)
- For diagnostic exam, follow with MR or CT
- **Alternate approach: Posterior transtriceps approach**
  - Use standard patient positioning
  - Palpate medial and lateral epicondyles and olecranon
  - On skin, mark needle entry point equidistant between epicondyles and just proximal to superior tip of olecranon
  - Advance needle until it contacts bone in olecranon fossa
  - Confirm location fluoroscopically
  - This approach avoids iatrogenic contrast extravasation into lateral collateral ligaments, which can occur with injection of radiocapitellar joint

Findings and Reporting

- Describe any signs of arthritis, synovitis, joint bodies

Alternative Procedures/Therapies

- Radiologic
  - US: Shows tendons, ligaments, synovitis
  - MR without arthrography: Decreased sensitivity for ligament/cartilage abnormalities

OUTCOMES

Problems

- Extravasation along lateral side of elbow
  - Due to superficial position of needle

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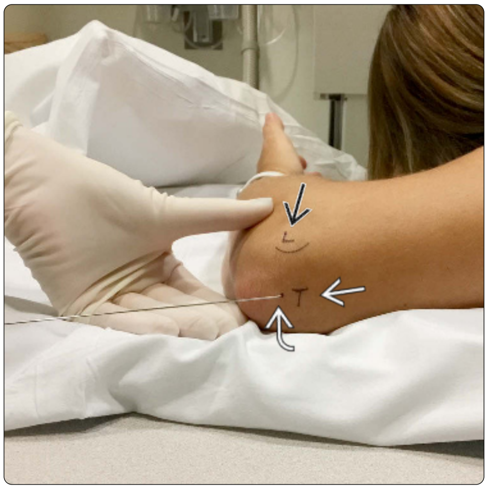
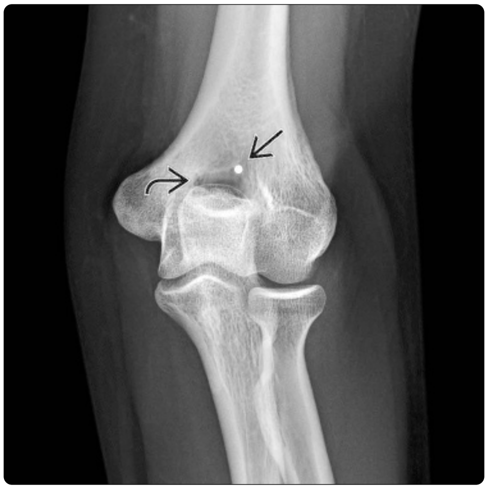
(Left) *Photograph shows planned injection site for posterior approach elbow arthrogram. The medial and lateral epicondyles and olecranon are palpated. The skin is marked at a point halfway between the epicondyles, just above the olecranon process* ➡*. The lateral epicondyle* ⇨ *and triceps tendon* ➡ *are marked on the skin for illustrative purposes.* **(Right)** *AP elbow radiograph demonstrates the planned puncture site* ⇨ *for a posterior approach elbow arthrogram proximal to the tip of the olecranon* ⇨*.*

Elbow Arthrography: Posterior Approach (Puncture Site)

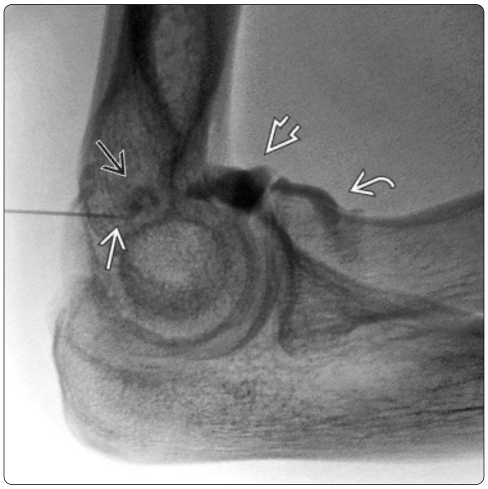


Elbow Arthrography: Posterior Approach (Puncture Site)

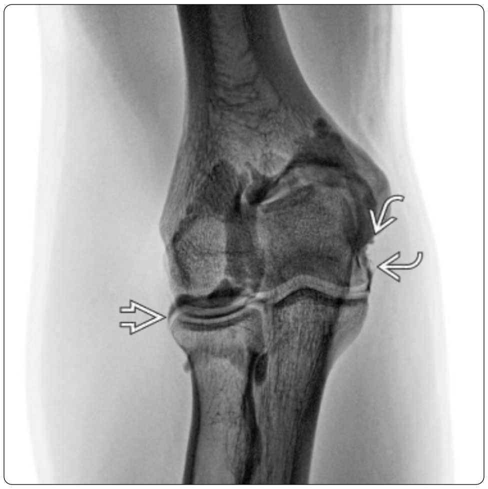


(Left) *Lateral elbow arthrogram shows the ideal needle position for a posterior approach, just proximal to the tip of the olecranon and contacting the olecranon fossa* ➡*. Contrast fills the olecranon* ⇨*, coronoid* ➡*, and radial* ➡ *recesses.* **(Right)** *AP elbow arthrogram shows irregularity of the ulnar collateral ligament* ➡ *reflecting a partial tear. The radial-sided structures are normal with contrast outlining the undersurface of the radial collateral ligament* ➡*.*

Elbow Arthrography: Posterior Approach (Fluoroscopic Imaging)

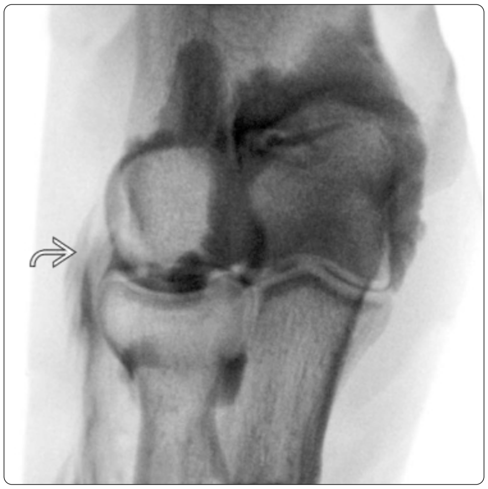


Ulnar Collateral Ligament Tear

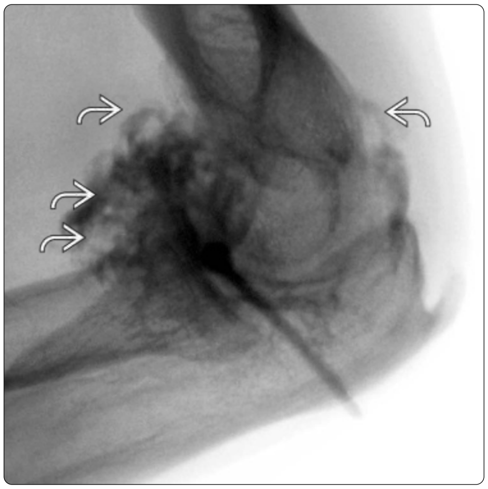


(Left) *Anteroposterior arthrogram shows good filling of the elbow joint but extravasation* ➡ *at the injection site along the extensor tendons. This artifact usually occurs at the initial phase of injection due to incomplete needle seating.* **(Right)** *Lateral arthrogram shows multiple filling defects* ➡ *in the injected contrast indicating synovitis in this patient with psoriatic arthritis.*

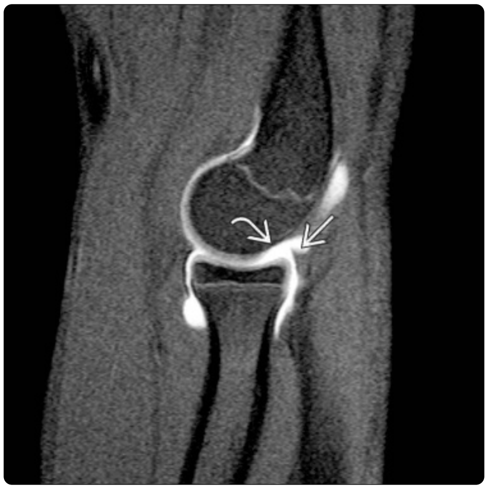
Contrast Extravasation



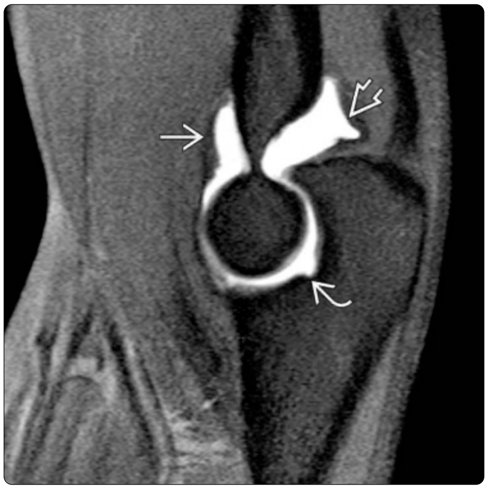
Synovitis



Radiocapitellar Joint (Sagittal)

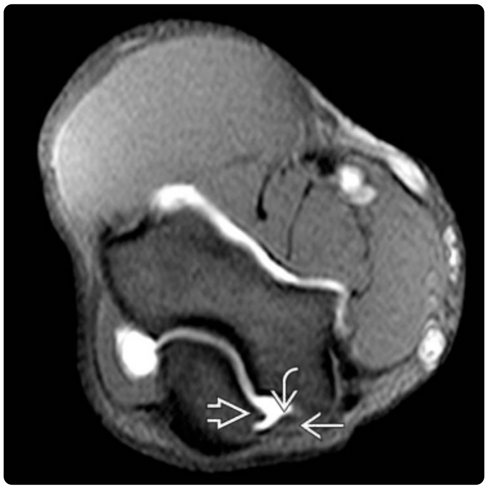


Ulnohumeral Joint (Sagittal)

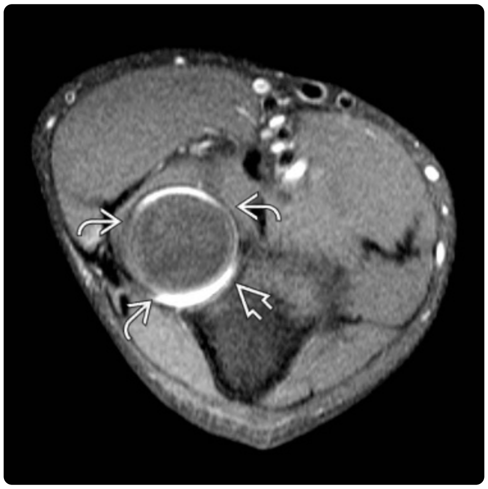


(Left) *Sagittal T1WI FS MR elbow arthrogram shows a normal radiocapitellar joint. The slight posterior concavity and the cartilage bare spot* ➡ *of the capitellum should not be mistaken for an osteochondral lesion. The triangular synovial fringe* ➡ *is a meniscal homologue.* **(Right)** *Sagittal T1WI FS MR arthrogram shows a normal trochlear ulnar joint. The trochlear cartilage has a central bowl-shaped bare spot* ➡*. The coronoid* ➡ *and olecranon* ➡ *recesses are anterior and posterior to the distal humerus.*

Ulnar Collateral Ligament (Axial)

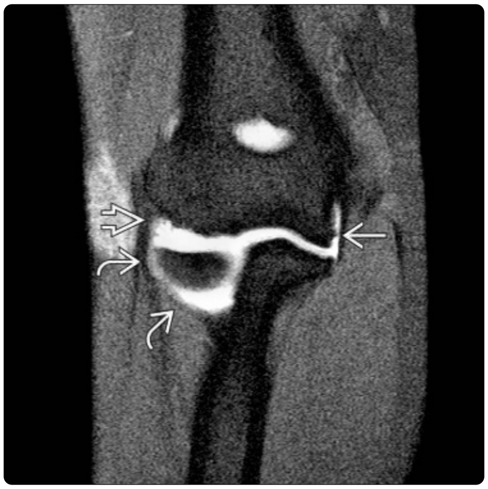


Proximal Radioulnar Joint (Axial)

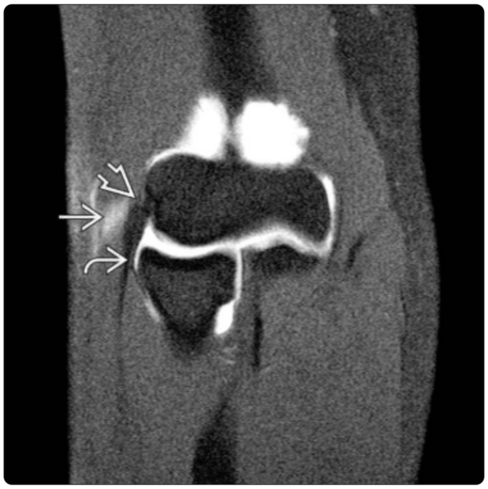


(Left) *Axial T1WI FS MR arthrogram shows the posterior band of the ulnar collateral ligament* ➡ *deep to the ulnar nerve* ➡*. Injuries to this ligament or osteophytes* ➡ *arising from the olecranon at this level may cause ulnar nerve impingement.* **(Right)** *Axial T1WI FS MR arthrogram shows the proximal radioulnar joint. This is a synovial joint that allows both supination and pronation. The proximal radius articulates with the sigmoid notch* ➡ *of the ulna. The annular ligament* ➡ *encircles the proximal radius.*

Ulnar Collateral Ligaments (Coronal)



Radial Collateral Ligament (Coronal)



(Left) *Coronal T1WI FS MR arthrogram shows the lateral ulnar collateral ligament* ➡*. Proximally, it merges with the radial collateral ligament* ➡*. The medial ulnar collateral ligament* ➡ *lies deep to the flexor muscles. It originates on the medial epicondyle and inserts on the sublime tubercle of the ulna.* **(Right)** *Coronal T1WI FS MR arthrogram shows the radial collateral ligament* ➡ *originating deep to the extensor carpi radialis brevis muscle* ➡ *and inserting on the annular ligament. Note the iatrogenic contrast extravasation* ➡*.*

Wrist Arthrography

KEY FACTS

PREPROCEDURE

- **Indications**
  - Most commonly performed to assess for ligament tear (scapholunate, lunotriquetral, triangular fibrocartilage complex)

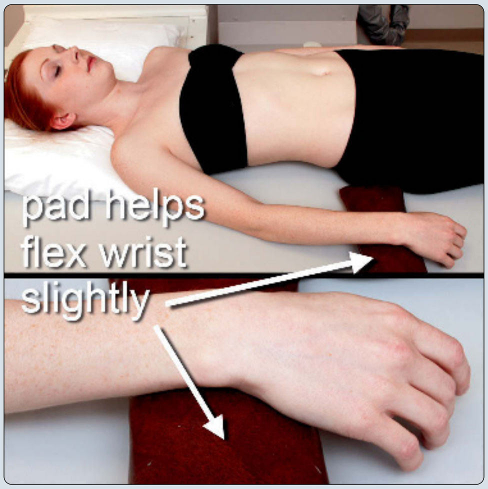
PROCEDURE

- 3 different patient positions can be used
  - Patient prone with arm over head, hand pronated with roll under wrist for slight flexion
  - Patient supine with arm by side, hand pronated with roll under wrist for slight flexion
  - Patient sitting next to table with arm extended under image receptor
- Injections generally performed via dorsal approach
- Radiocarpal joint injection is standard
- Tricompartment injection (radiocarpal, midcarpal, distal radioulnar joint) may also be rarely performed
- Monitor injection under fluoroscopy to watch for abnormal extracompartmental communication
- Inject until firm resistance met
  - Radiocarpal joint capacity ~ 2-3 mL
  - Midcarpal joint capacity ~ 2 mL
  - Distal radioulnar joint capacity ~ 1 mL

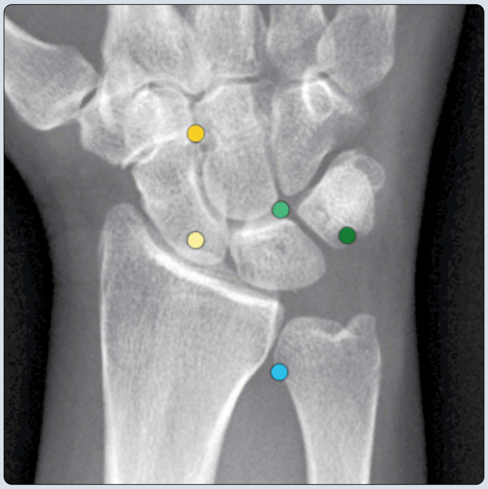
POST PROCEDURE

- MR with 3 planes of imaging, small FOV coil
  - T2WI FS or PD FS sequences
  - T1WI sequence without fat saturation and T1WI sequence with fat saturation in coronal plane
- CT with multiplanar reformation

Patient Positioning

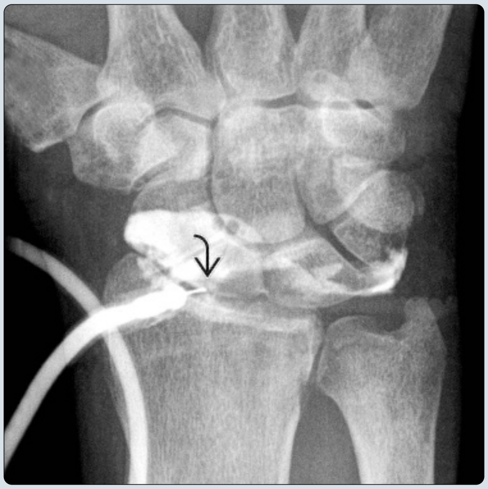


Injection Sites for Wrist Arthrography

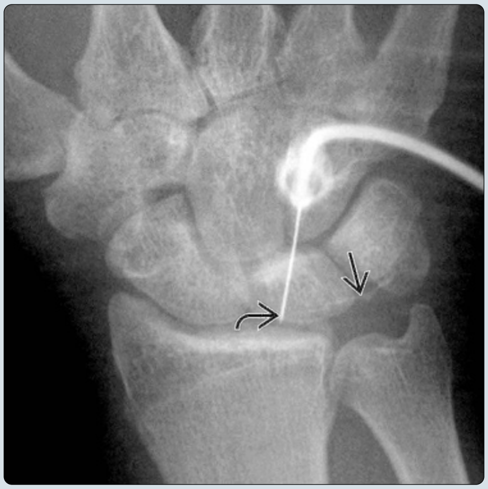


(Left) *Photograph shows one method of positioning for wrist arthrography. Alternative positions are: (1) Patient prone, arm over the head or (2) patient sitting beside fluoroscopy table, arm on table in front of the body.* **(Right)** *Image shows typical target sites. The radiocarpal joint can be targeted at proximal scaphoid pole (most common, light yellow) or proximal triquetrum (dark green). Blue dot denotes distal radioulnar joint (DRUJ) target site, while dark yellow and light green dots denote midcarpal target sites.*

Radiocarpal Joint Injection



Conventional Wrist Arthrogram (Early Radiocarpal Joint Filling)



(Left) *Frontal fluoroscopic spot radiograph shows the most common site for radiocarpal injection, the radioscaphoid joint ↗. Target is the proximal scaphoid pole. This is generally the only joint injected for CT or MR arthrography. The joint capacity is usually ~ 2-3 mL.* **(Right)** *AP wrist arthrogram shows early radiocarpal joint filling. The needle tip ↪ is placed adjacent to the proximal lunate and can be felt to slip past the bone. Contrast flows away from the needle tip within the joint →.*

Wrist Arthrography

TERMINOLOGY

Definitions

- **Single compartment arthrography** (most common)
  - Radiocarpal compartment injection
  - MR (ideally) or CT follow to optimally assess for ligamentous injury
- **Tricompartment arthrography** (rarely performed in current practice)
  - Sequential injections of radiocarpal, midcarpal, and distal radioulnar joints
    - Short time delay between injections permits contrast to dissipate
  - Slightly increased sensitivity to small ligament tears, particularly partial tears

PREPROCEDURE

Indications

- Ligament tear [scapholunate, lunotriquetral, triangular fibrocartilage complex TFC)]
- Cartilage injury/intraarticular body

Getting Started

- 22- to 25-gauge, 1.5-inch needle generally utilized to enter joints about wrist

PROCEDURE

Patient Position/Location

- Best procedure approach
  - 3 different patient positions can be used
    - Patient prone with arm over head, hand pronated; roll placed under wrist for slight flexion
    - Patient supine with arm by side, hand pronated; roll placed under wrist for slight flexion
    - Patient sitting next to table with arm extended under image receptor
      - ☐ Position allows patient to watch needle entry; can predispose to vasovagal episode

Procedure Steps

- **Radiocarpal injection**
  - **Dorsal approach (most common)**
    - Several possible injection sites
      - ☐ Most common site is along proximal scaphoid pole, just distal to dorsal radius
      - ☐ In cases with radial-sided pain, may also inject at ulnar side of carpus, along proximal edge of triquetrum
      - ☐ Avoid injecting near expected location of intercarpal ligaments
      - ☐ Avoid dorsal lip of radius, which is furthest distal radial surface seen on fluoroscopy
    - Advance needle into joint, utilizing bone as backstop for depth
    - Intraarticular contrast flows freely from needle tip
    - Monitor contrast injection under fluoroscopy to ensure intraarticular placement
    - Inject ~ 2-3 mL to distend joint or until firm resistance met
    - After removing needle, maneuver joint in ulnar and radial deviation; watch under fluoroscopy for any contrast extension into midcarpal or distal radioulnar joints
  - **Lateral approach**
    - Patient's hand in loose fist, radial side up
    - Place needle over proximal scaphoid, just distal to radial styloid
    - Rotate wrist into pronated position for posteroanterior fluoroscopy; inject under fluoroscopic visualization
- **Midcarpal injection**
  - May show subtle, partial tears not seen on radiocarpal injection
  - Target: "4 corners" interval, from dorsal approach, at confluence of triquetrum, lunate, capitate, and hamate
  - Place needle straight down into joint, and inject under fluoroscopic visualization
  - Inject ~ 2 mL to distend joint or until firm resistance met
- **Distal radioulnar joint injection**
  - Target radial margin of distal ulna, just proximal to physeal scar, via dorsal approach, and advance to bone
    - Can direct tip radially at this point into joint space
  - Inject ~ 1 mL to distend joint or until firm resistance met

Findings and Reporting

- Assess for ligament tear, and for complete ("communicating") tear, with abnormal extracompartmental communication of contrast
- Also assess for other sources of symptoms of subsequent MR

POST PROCEDURE

Post Procedure Imaging

- MR in 3 planes (axial/coronal/sagittal)
  - T2WI FS or PD FS sequences
  - T1WI sequence without fat saturation and T1WI sequence with fat saturation in coronal plane
- CT with multiplanar reformation

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7. Zlatkin MB et al: MR imaging of ligaments and triangular fibrocartilage complex of the wrist. Magn Reson Imaging Clin N Am. 12(2):301-31, vi-vii, 2004
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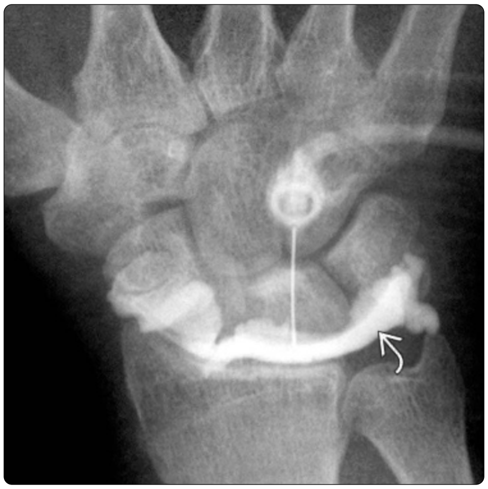
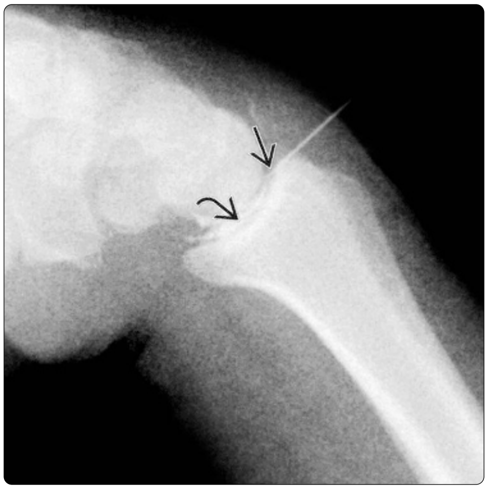
(Left) *AP wrist arthrogram shows late joint filling ↪. There is excellent radiocarpal joint distention and no extravasation of contrast into the DRUJ (TFC complex is intact) or the midcarpal joint (scapholunate and lunatotriquetral ligaments are intact).* **(Right)** *Lateral arthrogram confirms correct placement of the needle tip ⇨ between the lunate and the radius. Early joint filling with contrast ↪ is visible. Turning the wrist to confirm correct needle placement is a useful maneuver, especially for inexperienced arthrographers.*

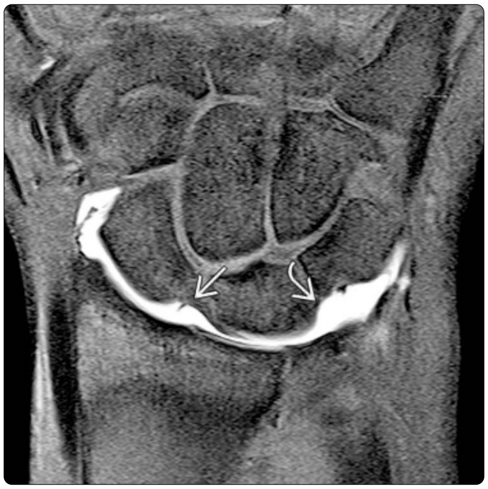


Conventional Wrist Arthrogram (Late Radiocarpal Joint Filling)

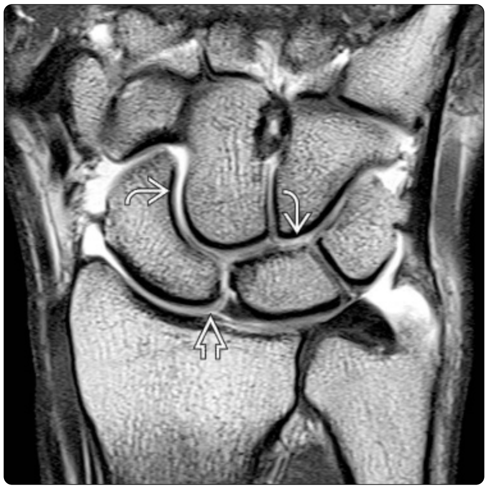


Confirming Needle Placement (Lateral View of Wrist)

(Left) *Coronal T1WI FS MR after radiocarpal injection shows excellent joint distention. The scapholunate → and lunatotriquetral ↪ ligaments are intact. There is no contrast extravasation into the midcarpal or distal radioulnar compartments.* **(Right)** *T1WI MR arthrogram after radiocarpal injection shows contrast extravasation from radiocarpal into midcarpal compartment ↪ through scapholunate ligament tear ⇨.*

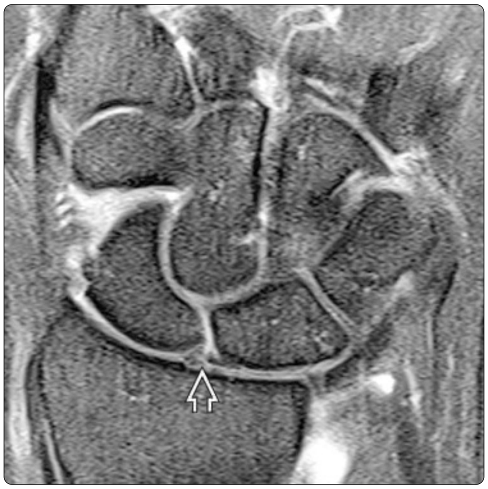


Direct MR Wrist Arthrogram (Normal Radiocarpal Joint)

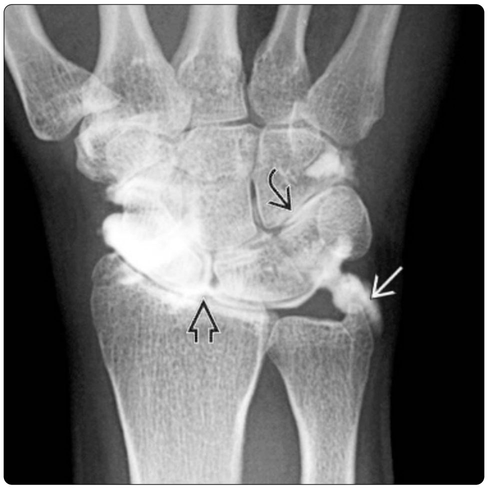


Direct MR Wrist Arthrogram (Scapholunate Ligament Tear)

(Left) *T1WI FS indirect MR arthrogram after IV contrast and exercise shows a scapholunate tear ⇨ outlined on both sides by contrast excreted into all joint compartments by synovium. Joint distention is less than with direct arthrography.* **(Right)** *Conventional arthrogram shows contrast filling the midcarpal joint ↪ after a radiocarpal injection. Contrast extends through the scapholunate ligament ⇨, identifying it as the site of abnormality. Note the normal recess adjacent to the ulnar styloid →.*

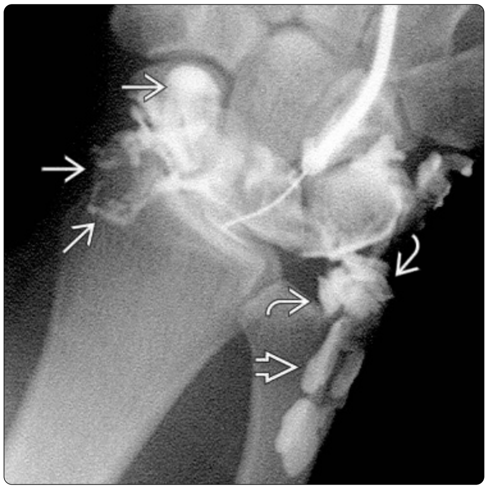


Indirect MR Arthrogram (Scapholunate Ligament Tear)

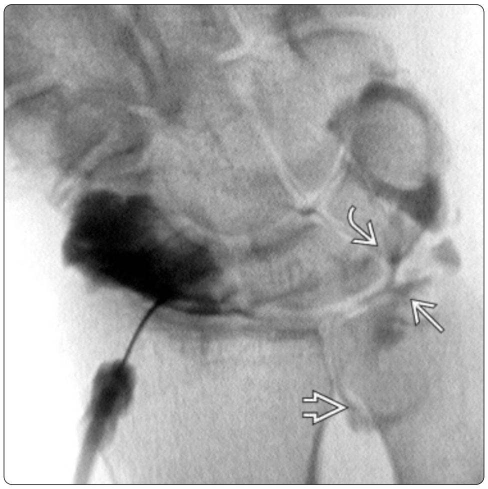


Conventional Wrist Arthrogram (Scapholunate Ligament Tear)

Conventional Wrist Arthrogram (TFC Tear)

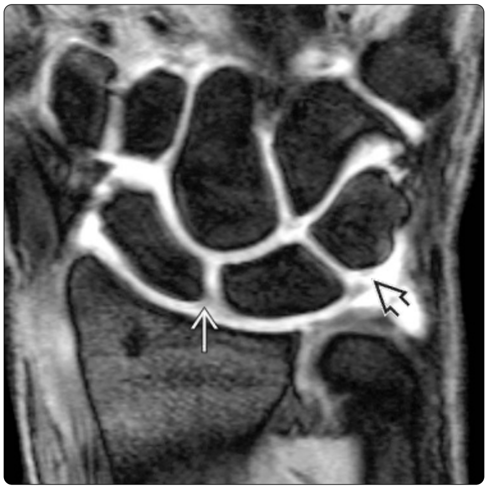


Conventional Wrist Arthrogram (Lunatotriquetral and TFC Tears)

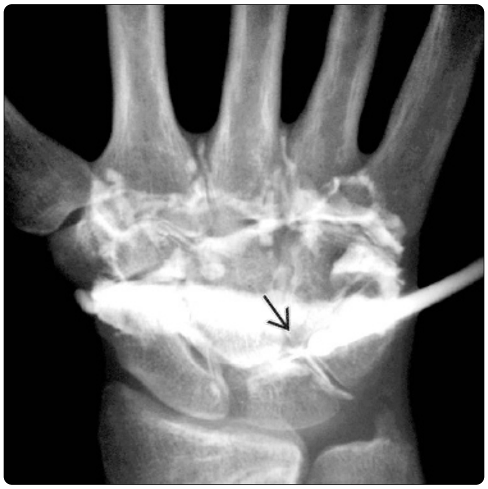


(Left) *Wrist arthrogram shows a peripheral triangular fibrocartilage complex (TFC) tear ↪. Contrast extends through the torn extensor carpi ulnaris tendon sheath, a part of the TFC complex, along the course of the tendon ⇨. The radial joint recesses → on the volar aspect are normal.* **(Right)** *Conventional wrist arthrogram of a radiocarpal injection shows contrast extension into the DRUJ ⇨ through a TFC tear → and into the midcarpal compartment through a lunatotriquetral tear ↪.*

Coronal Direct MR Arthrogram (Lunatotriquetral Ligament Tear)

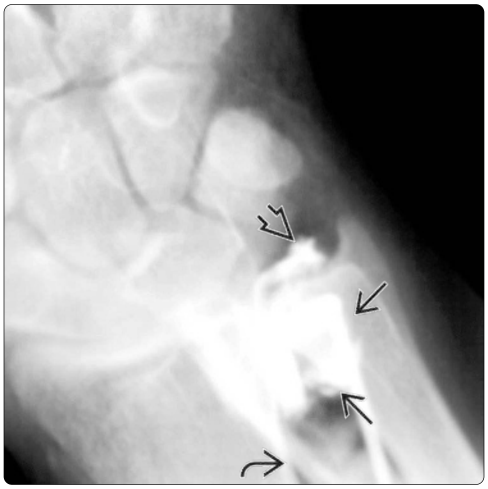


Conventional Wrist Arthrogram (Injection of Midcarpal Joint)

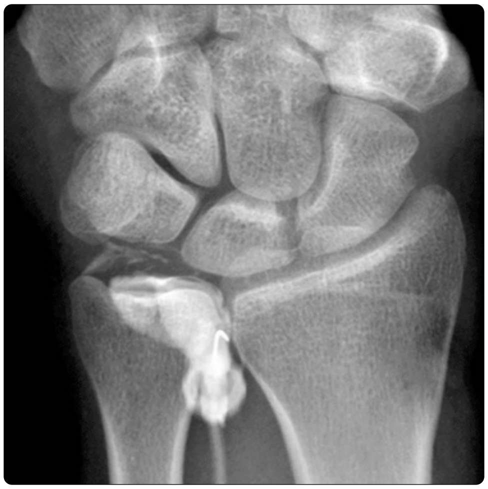


(Left) *Coronal direct MR wrist arthrogram shows a tear of the lunatotriquetral ligament ⇨ with a normal scapholunate ligament →. Dual-echo steady state images provide thin slices and high resolution, but often, there is increased motion due to the lengthy imaging time that is required.* **(Right)** *Frontal fluoroscopic spot radiograph shows an injection between the hamate and the lunate ("4 corners" area) →. There is normal filling of the intercarpal and the carpometacarpal joints.*

Conventional Wrist Arthrogram (DRUJ Injection)



Conventional Wrist Arthrogram (DRUJ Injection, TFC Complex Tear)



(Left) *Conventional AP wrist arthrogram shows filling of the DRUJ → and irregularity ⇨ of the undersurface of the TFC, indicating a partial thickness tear. The contrast extravasation along the extensor tendons ↪ is iatrogenic.* **(Right)** *Injection into the DRUJ is noted. There is abnormal contrast extension into the ulnocarpal joint space (yellow arrow) due to a TFC complex tear.*

Hip Arthrography

KEY FACTS

PREPROCEDURE

- Indications
    - Evaluate cartilage and labral injury
    - Therapeutic
        - Anesthetic & corticosteroid
    - Anesthetic arthrogram
        - Helps to confirm intraarticular source of pain
    - Aspiration for suspected infection or crystalline disease
- Contraindications
    - Overlying soft tissue infection
    - Coagulopathy (relative)

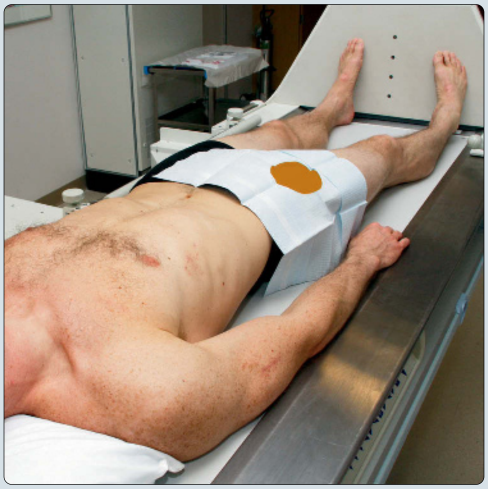
PROCEDURE

- Patient position
    - Patient supine
    - Hip slightly internally rotated and sandbag placed on outer aspect of foot to maintain internal rotation
- Localize lateral femoral head and neck junction
- Administer local anesthesia with 1% lidocaine
- Advance 3.5" 20-22 gauge needle into hip joint until needle contacts bone
    - Use 18 g for aspiration of suspected infection
- Remove inner stylet and perform contrast injection while monitoring fluoroscopically
    - Injection volume: 10-18 mL
- Obtain postprocedure fluoroscopy spot images

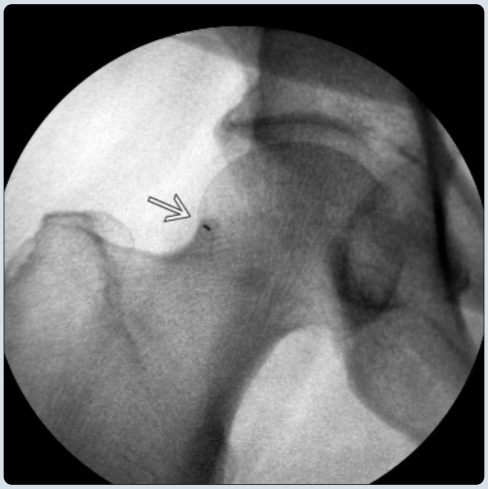
OUTCOMES

- Problems
    - Extraarticular injection
- Complications
    - Infection (rare)
    - Femoral nerve anesthesia
    - Bleeding
    - Pain

Patient Positioning

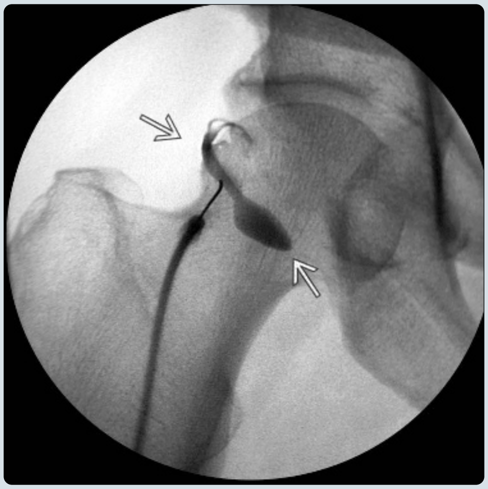


Hip Arthrogram: Needle Position

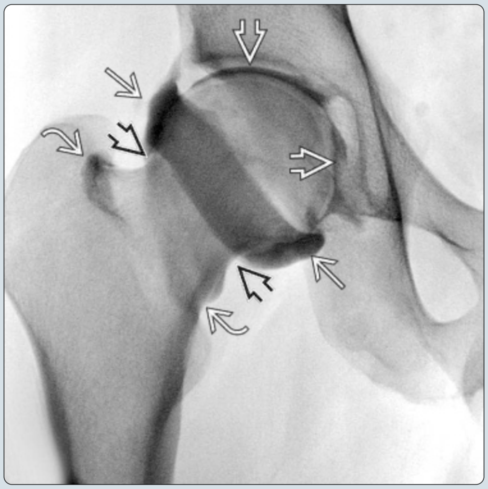


(Left) *This patient is positioned with the hip internally rotated, placing the iliopsoas tendon medially to avoid bursal injection. The femoral neurovascular bundle must be avoided. Several approaches to the joint may be used.* **(Right)** *Fluoroscopic spot image demonstrates the ideal position of the needle, at the lateral aspect of the femoral head and neck junction →. Needle is oriented perfectly straight, with the hub projecting over the needle tip.*

Hip Arthrogram: Early Filling



Hip Arthrogram: Late Filling



(Left) *Fluoroscopic spot image obtained during the initial injection demonstrates contrast flowing away from the needle tip and filling the normal joint recesses →.* **(Right)** *AP hip arthrogram shows a completed arthrogram with good joint distention. Contrast outlines the articular surfaces ⇨. The superior → and inferior joint recesses ↪ are separated by the zona orbicularis ⇨.*

PREPROCEDURE

Indications

- Cartilage and labral injury
- Therapeutic
    - Anesthetic & corticosteroid
- Anesthetic arthrogram
    - Anesthetic only
    - Helps to confirm intraarticular source of pain
- Aspiration for suspected infection or crystalline disease

Contraindications

- Overlying soft tissue infection
- Coagulopathy (relative)

Preprocedure Imaging

- Always double check radiographs to exclude subtle insufficiency fracture
    - Therapeutic injection of incomplete insufficiency fracture may cause fracture progression

Getting Started

- Things to check
    - Medical history: Bleeding risk, medication list
    - Allergies: For iodinated contrast allergy, either premedication can be administered, or injection can be performed under US guidance
        - If therapeutic injection or aspiration, air may also be used as contrast agent
    - Laboratory parameters
        - Routine labs not typically obtained prior to procedure; however, if patient on coumadin, check INR to ensure within therapeutic range
- Medications
    - 1% lidocaine for local anesthetic
        - May buffer 1:9 with sodium bicarbonate (optional)
    - Contrast solution for MR arthrography
        - 1 10-mL syringe of full-strength iodinated contrast to confirm intraarticular position of needle
        - 1 20-mL syringe of dilute gadolinium (0.1 mL gadolinium and 20 mL saline) for injection
        - Alternatively, some arthrographers prefer to mix iodinated contrast and gadolinium in single syringe
            - e.g., 0.1 mL gadolinium, 10 mL nonionic iodinated contrast, 10 mL saline
        - May replace some of diluent with anesthetic
    - Contrast solution for CT arthrography
        - 1:1 dilution iodinated contrast and saline
    - Therapeutic injection
        - Corticosteroid & anesthetic
        - e.g., 1 mL triamcinolone acetonide (40 mg/mL), 2 mL 0.5% ropivacaine, 2 mL 1% preservative-free lidocaine
    - Anesthetic arthrogram
        - 8 mL of 1:1 solution of 1% lidocaine and 0.5% ropivacaine
- Equipment list
    - Standard arthrogram tray
        - Sterile, fenestrated drape
        - Local antiseptic solution
        - 18-g and 25-g 1.5" needles
        - 1-mL, 5-mL, and 10-mL syringes
        - Sterile tubing
    - 3.5" spinal needle (20-22 g for injection, 18 g for aspiration)
        - May need longer needle for obese patients
    - Guidance equipment (fluoroscope)
    - Positioning aids (pillows, towels, wedges, etc.)
    - Skin localizer: BB on piece of tape or other marker
    - Indelible marker to mark skin

PROCEDURE

Patient Position/Location

- Patient supine
- Hip slightly internally rotated and sandbag placed on outer aspect of foot to maintain internal rotation

Equipment Preparation

- Prepare contrast solution, attach contrast-filled syringe to flush tubing and flush, ensuring there are no air bubbles

Procedure Steps

- **Best procedure approach**
    - **Lateral aspect of femoral head/neck junction (recommended)**
        - Localize lateral aspect of femoral head and neck junction fluoroscopically and mark overlying skin
        - Palpate femoral artery and ensure that it is not in needle trajectory
        - Using sterile technique, prep and drape injection site
        - Administer local anesthesia with 1% lidocaine
        - Advance spinal needle into hip joint using straight, vertical (bull's-eye) approach
        - When needle encounters bone, remove inner stylet
        - Drip contrast into needle hub (to eliminate air) and then attach contrast-filled flush tubing and syringe
        - While monitoring fluoroscopically, inject small amount of contrast to confirm intraarticular positioning of needle
            - Contrast should flow away from needle; if contrast pools around needle tip, it is not intraarticular and must be repositioned
        - Once intraarticular positioning of needle is confirmed, perform contrast injection
            - Injection volume: 10-18 mL
- **Alternate approach: Medial femoral head/neck junction**
    - Use straight vertical approach
    - Introduce needle over medial quadrant of femoral head/neck junction
    - When needle encounters bone, ease pressure and gently advance; curve needle slightly medially
    - Needle is in medial joint recess
    - Risk of femoral nerve anesthesia
- **Alternate approach: Central femoral head**
    - Use straight vertical approach
    - Introduce needle over center of femoral head
    - Advance needle to bone; ease pressure before injection
        - Forceful injection, especially in this location, may cause intraosseous injection
    - High risk of mixed intra- and extraarticular injection
        - Bevel of needle may be only partly intraarticular
- **Alternate approach: Oblique approach**
    - Enter skin over intertrochanteric region

  - Angle needle cephalad and medially along axis of femoral neck
  - Angle of approach 45-60° to table
  - Usually enter joint in either neck or head
  - Useful in obese patients where pannus overlies other approaches
  - Risk of bursal or mixed injection
- **Alternate approach: Lateral entry approach**
  - Palpate greater trochanter; mark superior margin
  - Confirm location with fluoroscopy
  - Introduce needle immediately superior to greater trochanter
  - Advance needle into hip joint, keeping needle parallel to fluoroscopy table
  - Can be useful to avoid needle passage through any area of anterior cellulitis
  - Difficult in obese patients if greater trochanter is not palpable
- **Hip and hip arthroplasty aspirations**
  - Use 18-g needle
    - Infected fluid may be thick
  - Avoid areas of overlying cellulitis or soft tissue infection
  - Hip arthroplasty: Localize slightly lateral to lateral aspect of prosthetic femoral neck and aim for lateral edge of prosthesis
    - Difficult to visualize needle overlying metallic prosthesis
  - Pass 18-g needle into joint until needle contacts bone (or metal)
    - In hip arthroplasty, pseudocapsule may be heavily calcified, simulating bone
    - Must feel needle tip contacting metal
  - If fluid comes back readily, aspirate at this point
  - If no spontaneous fluid return, inject small amount of iodinated contrast to verify intraarticular position
  - Aspirate again; if no fluid return, try using smaller syringe
    - Easier to aspirate with 5-mL than 10-mL syringe
  - "Walk" needle to different regions of joint
  - If still no fluid return, inject 10 mL sterile saline; aspirate back immediately
    - Often recommended method but low yield
  - Collect specimen and send for analysis
    - Gram stain, culture, cell count; any other requested labs

Findings and Reporting

- Therapeutic injection
  - Pain response to injection
- Aspiration
  - Amount and appearance of fluid (color, clarity, viscosity)
    - Normal synovial fluid straw-colored and clear

Alternative Procedures/Therapies

- Radiologic
  - Noncontrast MR
    - Meta-analysis suggests MR arthrography is superior to noncontrast MR for detection of labral tears in adults
  - Indirect MR arthrography
    - Indirect arthrography has been shown to be accurate tool for diagnosis of labral tears, but less useful for detection of cartilage lesions

OUTCOMES

Problems

- Joint may be difficult to access in obese patients due to pannus
  - Tape pannus out of way; tape across table & abdomen
  - Use long (5") spinal needle
- **Extraarticular or mixed injection**
  - Tip of needle may be within joint, but bevel lies within or outside joint capsule
  - Pull back a few mm, rotate needle so that bevel faces curve of bone, aim for lateral edge of bone and gently advance until needle contacts bone
- **Inadvertent iliopsoas bursa injection**
  - Occurs with injection over center of femoral head or oblique approach
  - Mixed injection causes poor joint distention

Complications

- Most feared complication(s)
  - Infection (rare)
    - Symptoms may occur in several days or be delayed 1 month or more
- Other complications
  - Femoral nerve anesthesia
    - May occur when anesthetic injection done at medial portion of joint
    - Lidocaine diffuses around femoral nerve
      - Usually not direct injection into nerve, so no pain at time of injection
    - Results in transient thigh weakness
      - Lasts for about 30 min with lidocaine injection
    - Assist patient off of fluoroscopy table to be certain there is no thigh weakness
  - Bleeding
  - Pain
    - Usually < 24 hours; sometimes several days
    - Counsel patients to limit strenuous physical activity after arthrogram
    - Responds to acetaminophen, NSAIDs, and often to diphenhydramine

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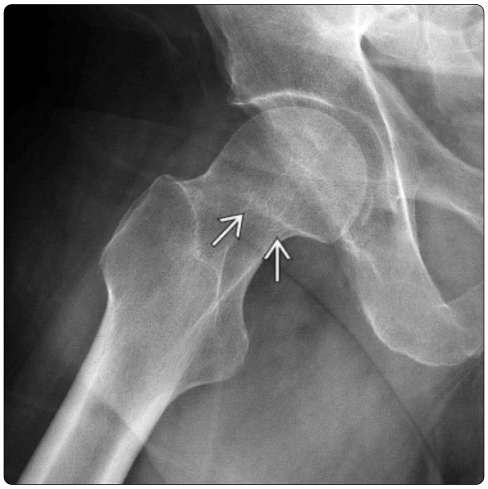
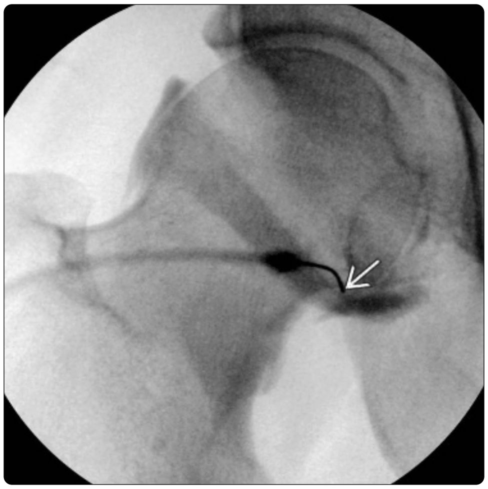
Femoral Neck Stress Fracture

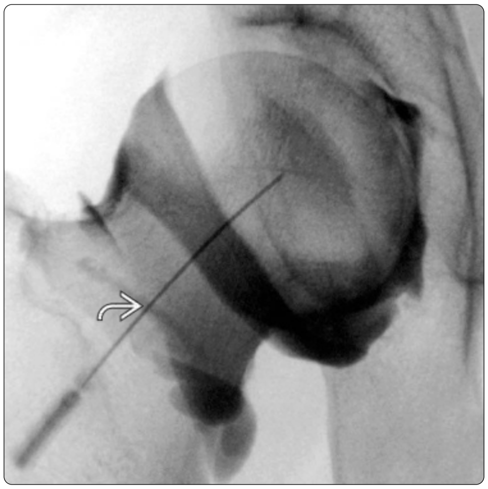


Medial Approach

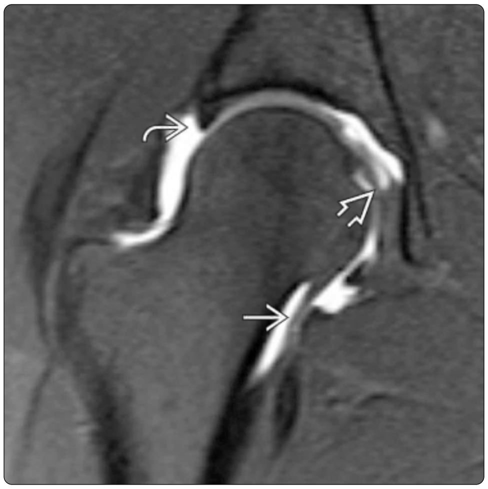


(Left) *Frog leg lateral radiograph demonstrates a stress fracture* ➔ *at the head/neck junction. This was confirmed on subsequent CT. Intraarticular steroid injection of stress fractures in this location may impede healing and lead to fracture progression.* **(Right)** *AP hip arthrogram shows a medial needle position* ➔*, which is technically simple because of large joint recess. However, it also carries risk of inadvertent femoral nerve anesthesia & transient thigh weakness.*

Oblique Approach

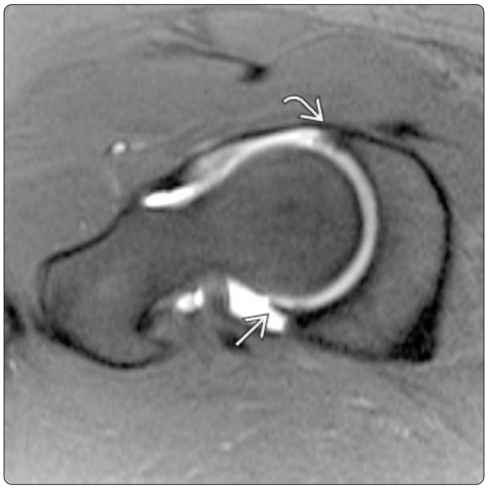


Normal Coronal MR Arthrogram

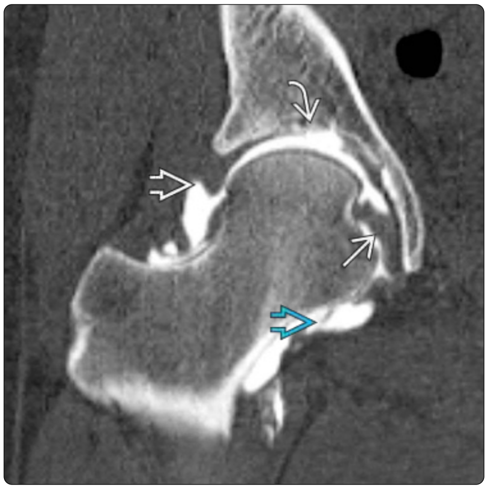


(Left) *AP hip arthrogram shows an oblique approach, entering skin at the intertrochanteric line* ↷ *& angling the needle along the femoral neck. It can be difficult to gauge depth with this approach; the needle may be too shallow in obese patients or strike the femoral neck at the zona orbicularis where capsule is tight.* **(Right)** *Coronal T1 FS MR arthrogram shows a joint that has been well distended with contrast, with a normal labrum* ↷*, iliopectineal fold* ➔*, and ligamentum teres* ⇨*.*

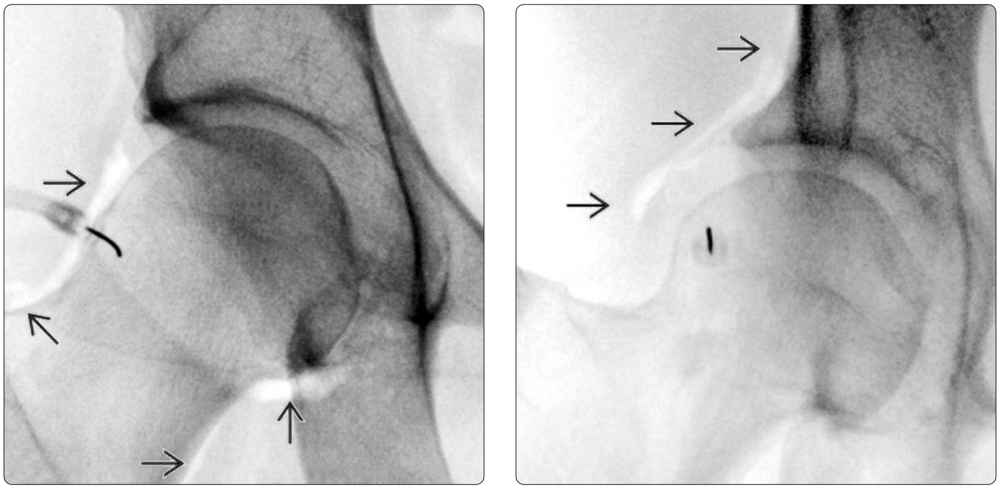
Normal Axial Oblique MR Arthrogram



Normal Coronal CT Arthrogram

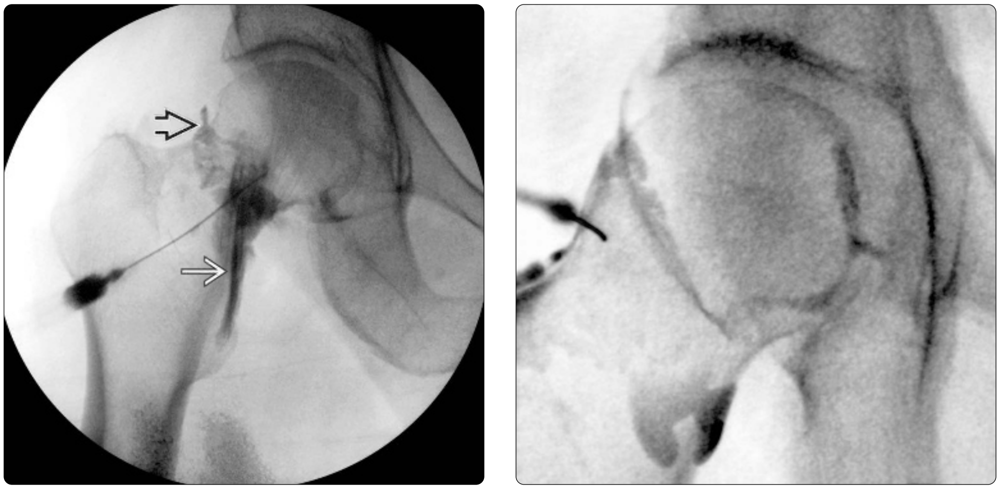


(Left) *Axial oblique T1 FS MR arthrogram shows the intact anterior* ↷ *and posterior* ➔ *labrum.* **(Right)** *Coronal CT arthrogram shows a bare area and underlying stellate defect* ↷ *in the superomedial acetabulum, thought to be a normal variant. Also note the normal ligamentum teres* ➔*, iliopectineal fold* ⇨*, and a large intact superior labrum* ⇨*. CT arthrography is excellent for evaluation of hyaline cartilage, but labral tears are less readily seen than on MR arthrogram.*



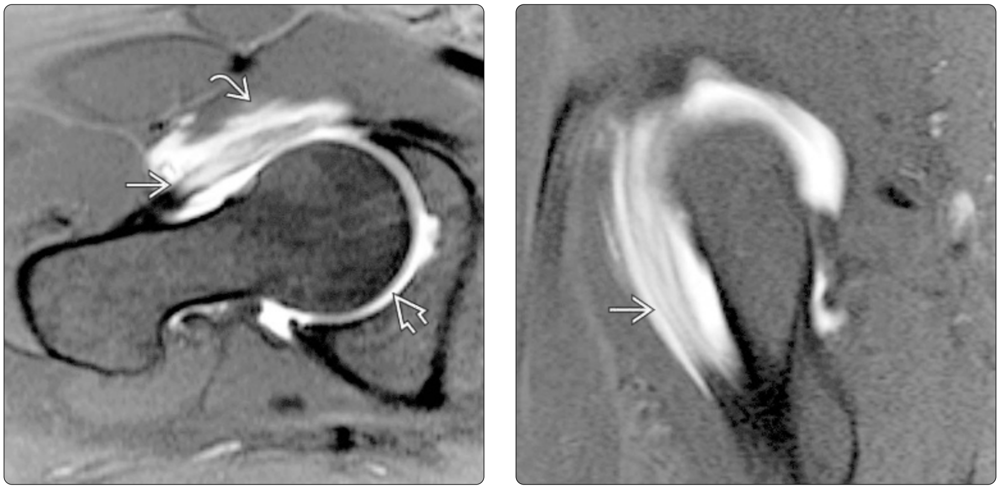
Air Arthrogram | **Extracapsular Air Injection**

(Left) *Anteroposterior arthrogram using air contrast shows excellent filling of the joint recesses* → *. Air can be used for therapeutic injections & for fluid aspiration and avoids the potential for allergic reaction or pain related to contrast injection.* **(Right)** *AP arthrogram shows extracapsular air* → *outlining the iliofemoral ligament. The needle tip is on the joint capsule, which feels firm to the needle and may be mistaken for bone by an inexperienced arthrographer. At this point, the needle should be advanced further.*



Mixed Hip Injection | **Extraarticular Injection**

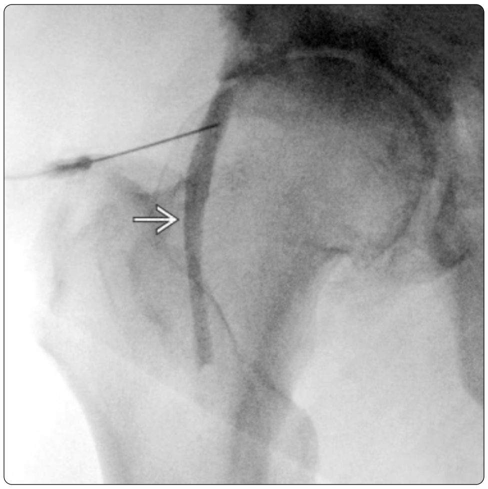
(Left) *AP right hip arthrogram shows a mixed injection of the contrast into the iliopsoas bursa and tendon sheath* ➡ *and also the hip joint* ⇨ *from an oblique approach. Poor joint distention limits MR visualization of the cartilage and labrum.* **(Right)** *AP hip arthrogram shows an unsuccessful zona orbicularis injection. The contrast outlines the exterior of the joint, but does not enter the joint space. Injection in this case was difficult, but sometimes extraarticular contrast flows easily in the potential spaces that surround the hip.*



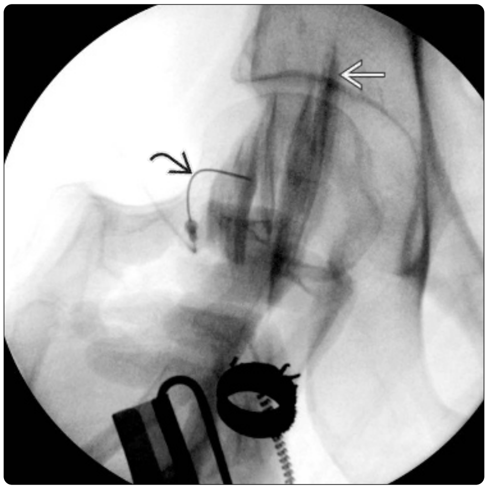
Mixed Injection, MR Arthrogram | **Mixed Injection, MR Arthrogram**

(Left) *Axial oblique T1 FS MR right hip arthrogram shows that the contrast splits the layers of the iliofemoral ligament* ➡ *, mimicking a capsule injury. The contrast is also extraarticular* ➡ *, and there is only a small amount of intraarticular contrast* ➡ *identified.* **(Right)** *Sagittal T1 FS MR arthrogram in the same patient shows the extent of misplaced contrast between the layers of the iliofemoral ligament* ➡ *.*

Incorrect Needle Placement

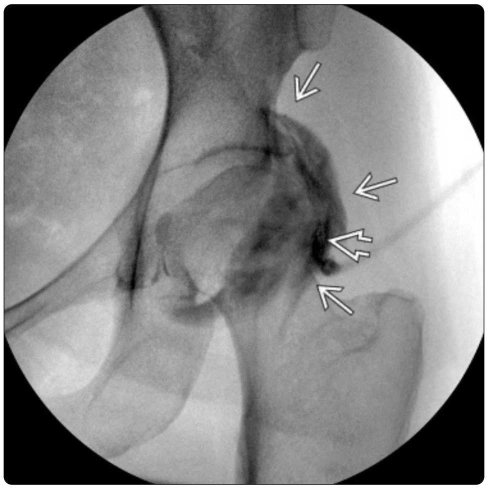


Incorrect Needle Placement

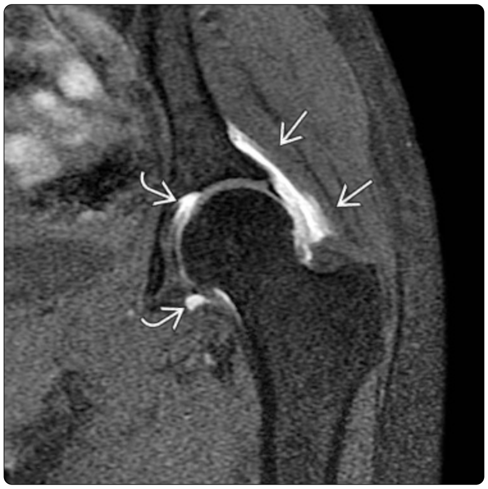


(Left) *AP arthrogram shows contrast in the iliofemoral ligament →. The injection is lateral to the iliopsoas bursa and, unlike bursal contrast, does not extend toward the lesser tuberosity of the femur. The needle should be advanced.* **(Right)** *AP hip arthrogram shows the operator's hand in the field of view while pressure is applied on a bent needle ↪. The hand and the bent needle are signs that a high force was needed to inject contrast. Contrast is in the iliopsoas muscle and sheath →.*

Extraarticular Injection

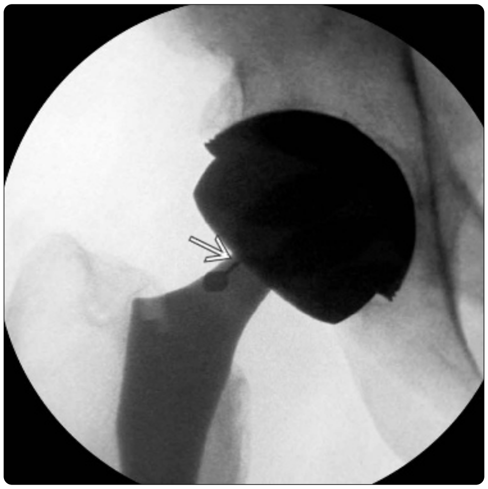


Extraarticular Injection, MR Arthrogram

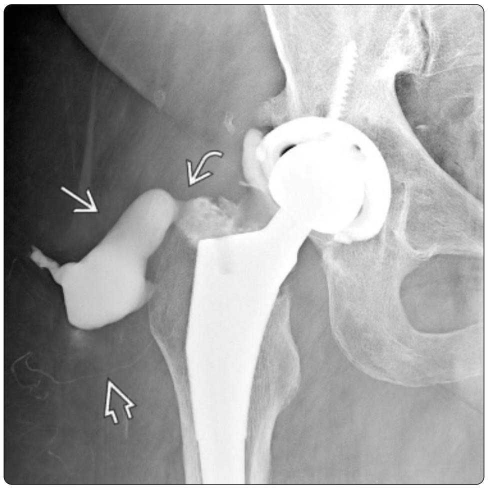


(Left) *AP hip arthrogram shows an extraarticular injection, with the needle tip located lateral to the femoral head ⇨, and contrast dissecting through the layers of the joint capsule →. The needle should be pulled back, redirected slightly medially, and advanced until it contacts bone.* **(Right)** *Coronal T1 FS MR arthrogram in the same patient shows contrast dissecting through the hip capsule →, with only a small amount of contrast within the joint ↪.*

Hip Arthroplasty Aspiration



Periprosthetic Fluid Collection



(Left) *AP fluoroscopic spot view during hip aspiration shows that the joint is entered over the superolateral aspect of the neck of the femoral prosthesis →.* **(Right)** *AP arthrogram obtained after hip aspiration shows contrast filling a defect in the lateral hip capsule ↪, which communicates with a fluid collection lateral to the greater trochanter →. Also note intravasation of contrast into the lymphatics along the lateral aspect of the right hip and thigh ⇨. In this case, infection was suspected clinically.*

Sacroiliac Joint Arthrography

KEY FACTS

PREPROCEDURE

- Therapeutic Indication: Steroid/anesthetic injection for pain relief
- Diagnostic Indication: Aspiration, when there is concern for infection

PROCEDURE

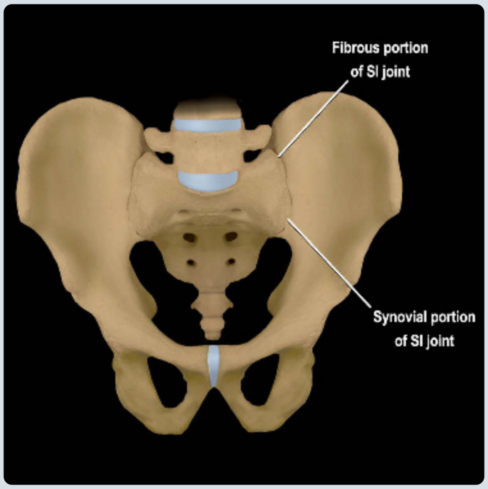
- May utilize either fluoroscopy or CT for guidance; CT provides ideal visualization and confirmation of needle tip location
- Localize injection site with marker
- The sacroiliac (SI) joint is obliquely oriented from posteromedial to anterolateral
  - Aim for inferior margin of joint (primarily synovial at this site)
  - Also aim for posterior aspect of joint
- Avoid superior portion of SI joint
  - Primarily ligamentous, not synovial
- SI joint has small capacity for injections
- Therapeutic: Inject 1-2-mL of contrast if performing under fluoroscopy; not needed with CT
  - Generally inject 1 mL steroid with 0.5-1 mL of anesthetic
  - Inject steroid first, to ensure entirety of steroid volume can be delivered into joint
- For infection: Do not inject contrast; aspirate for fluid

POST PROCEDURE

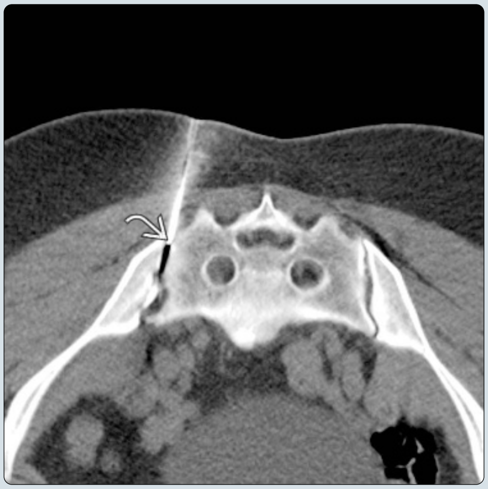
- High success rate for pain treatment
- Some patients may have short-term worsening of pain before corticosteroid takes full effect
- Postprocedure reporting
  - Therapeutic: Report level of pain before and after procedure (scale of 1-10)
  - Infection: Report appearance and amount of fluid withdrawn

(Left) *The synovial and fibrous portions of the SI joint are shown in an anterior view. Therapeutic injections should target the synovial portion of the SI joint, which is regarded as the inferior 1/3 or inferior 2/3 of the joint.* **(Right)** *Axial CT shows needle placement under CT guidance. The needle tip ↪ is positioned at the posterior SI joint margin. Note that the needle is angled slightly to parallel the course of the joint. Contrast injection is not required, given excellent needle visualization and small joint capacity.*

Pelvis & Sacroiliac Joint

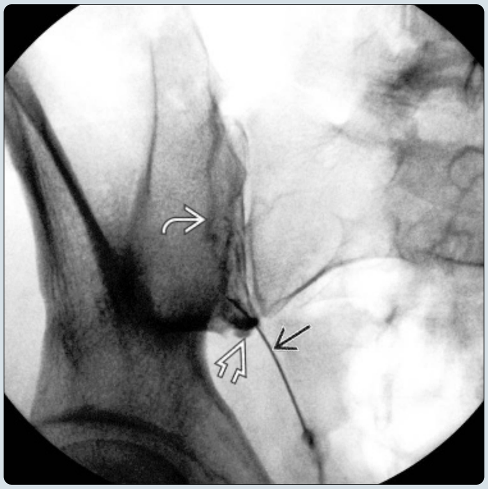


CT-Guided Sacroiliac Joint Injection

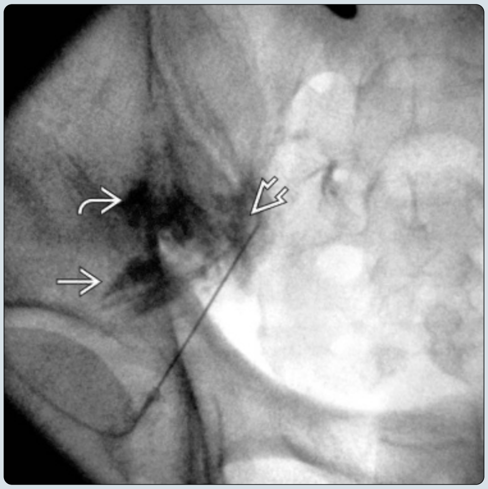


(Left) *Fluoroscopic spot radiograph shows a needle → ideally positioned for SI joint arthrography. The posterior joint line is well seen; the anterior joint line is lateral ↪. Contrast fills the entire joint, including a normal inferior recess ⇨.* **(Right)** *Anteroposterior fluoroscopic spot radiograph shows needle placement just medial to joint. Contrast is extracapsular ↪ and even intramuscular →. Medial joint line is visible ⇨ just lateral to needle tip.*

Fluoroscopically-Guided Sacroiliac Joint Injection



Fluoroscopically-Guided Sacroiliac Joint Injection with Contrast Extravasation



TERMINOLOGY

Definitions

- **Sacroiliac (SI) joint arthrography**: Contrast injection into SI joint
  - Therapeutic and diagnostic utility

PREPROCEDURE

Indications

- Therapeutic: Treatment of pain, most often due to arthritis &/or sacroiliitis
  - Steroid injection
- Diagnostic: Aspiration may be requested in cases of suspected infection
- If performed under CT, with direct visualization of needle placement in joint space, contrast injection is not necessary

Getting Started

- Medications
  - For therapeutic injection: Corticosteroid and anesthetic mix
    - SI joint has small capacity; generally can only accommodate 1-2 mL total
    - Most often, 1 mL of corticosteroid is injected into joint with 0.5-1.0 mL of anesthetic
  - Etanercept injection has been reported for treatment of ankylosing spondylitis
- Equipment list
  - 22-g, 3.5" needle most often utilized for joint injection

PROCEDURE

Patient Position/Location

- Best procedure approach
  - May be performed with fluoroscopic or CT guidance
    - CT guidance allows for ideal visualization
  - Patient prone

Procedure Steps

- Localize injection site with marker
  - Aim for inferior margin of SI joint
    - Avoid superior portion of SI joint
      - Primarily ligamentous, not synovial
  - Aim for posterior aspect of joint
    - SI joint has oblique orientation
      - Oriented from posteromedial to anterolateral
    - Fluoroscopic landmarks
      - Posterior joint projects medial to anterior joint
- Administer superficial and deep anesthesia
- Check position with anesthesia needle
- Advance 22-g spinal needle into joint
  - If needle tip is on bone, can "walk" needle over to joint space with tactile sensation and imaging guidance both confirming joint entry
- Therapeutic: Inject 1-2-mL of contrast to confirm position if utilizing fluoroscopy; not needed with CT
- For infection: Do not inject contrast; aspirate for fluid
  - Contrast is bacteriostatic
  - If no fluid, reposition needle
  - Can lavage joint gently with nonbacteriostatic saline

Findings and Reporting

- Therapeutic: Report pain level before and after procedure using standard 1-10 pain scale
- Infection: Report appearance and amount of fluid withdrawn

POST PROCEDURE

Things to Do

- Allow activity as tolerated
- Use acetaminophen, nonsteroidal antiinflammatory medications for pain management
- Have patient maintain log of pain relief
  - Report log results to referring clinician

Postprocedure Imaging

- Document needle placement and contrast injection
- Perform complete CT evaluation if using for guidance
  - Exclude other causes of pain in this region

OUTCOMES

Problems

- Needle entry too far cephalad
  - Cephalad 2/3 of SI joint primarily ligamentous
  - Small synovial joint in this region
    - Located anteriorly; difficult to access
- Needle entry too far lateral
  - Be sure to visualize posterior aspect of joint
    - Remember, posterior joint margin is medial to anterior portion of SI joint
  - If unsure, angle beam slightly until anterior and posterior margins are distinctly seen
- Radicular nerve pain during needle placement
  - May encounter superior gluteal nerve
    - Reposition needle and reassure patient

Expected Outcomes

- High therapeutic success rate for pain treatment
  - Some patients have short-term worsening of pain
    - Occurs before corticosteroid takes full effect

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Knee Arthrography

KEY FACTS

TERMINOLOGY

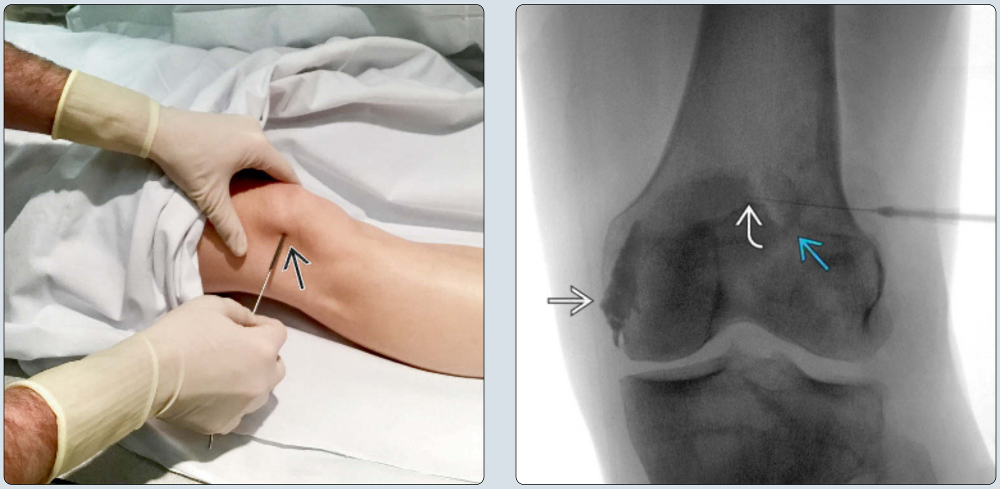
- **Knee arthrography**: Injection of contrast medium into knee joint followed by imaging

PREPROCEDURE

- **Indications**
    - Postmeniscectomy knee evaluation
    - Known/suspected hyaline cartilage defects
    - Evaluation of osteochondral lesions
- **Contraindications**
    - Overlying soft tissue infection

PROCEDURE

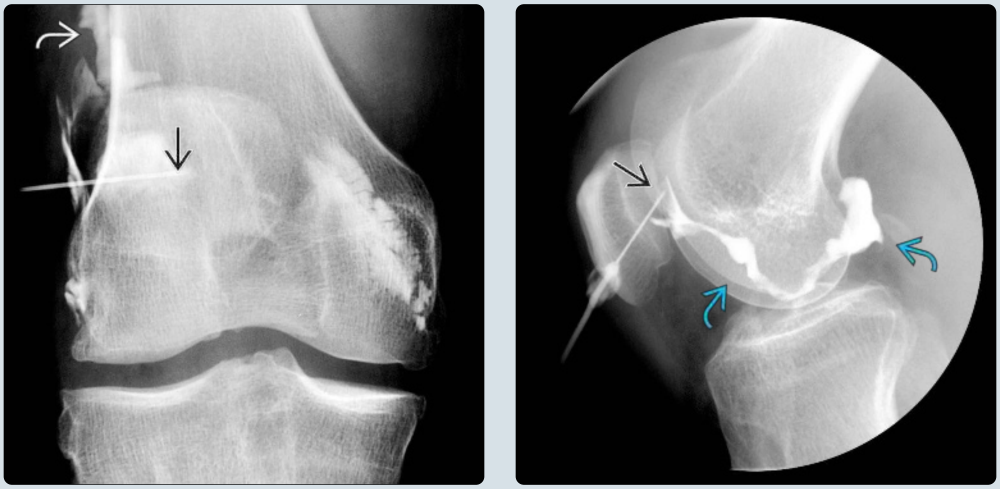
- Patient positioning
    - Patient supine with knee in either full extension or minimal flexion, toes pointing upward
- Approach
    - Lateral patellofemoral
        - Gently sublux patella laterally, palpate lateral edge of patella, and mark skin at its midpoint
        - While gently subluxing patella laterally, advance 20- to 22-g, 1.5" needle into joint, aiming for imaginary point in undersurface of center of patella
        - Injection volume: 30 mL
    - Alternate approach: Anterior
        - Useful in obese patients, when patella is not palpable, and in patients with severe patellofemoral osteoarthritis
        - Localize inferior aspect of femoral trochlea, just medial or lateral to patellar tendon
        - Advance 20- to 22-g, 1.5" needle into joint until needle contacts femoral trochlea
- Alternative procedures
    - MR without arthrography



Step-by-Step: Lateral Patellofemoral Approach

Step-by-Step: Lateral Patellofemoral Approach (Early Filling)

(Left) *Clinical photograph shows the planned entry point* ⇨ *for a lateral patellofemoral approach knee arthrogram. The lateral margin of the patella is palpated and the skin is marked at its midpoint. In most patients, the patella is easily palpated.* **(Right)** *Lateral patellofemoral approach knee arthrogram is shown. The needle overlies the lateral patella with the tip near the midline* ➡*. Contrast flows away from the needle and fills the normal joint recesses* ➡*. There is a bipartite patella* ⇨*, a normal variant.*



Step-by-Step: Lateral Patellofemoral Approach (Normal Joint Filling)

Step-by-Step: Lateral Patellofemoral Approach (Lateral View)

(Left) *The needle tip* ⇨ *was advanced to the mid patella. Contrast flows freely from the needle tip into the dependent joint recesses. The lateral suprapatellar recess* ➡ *extends lateral to the femur, and contrast seen in this region should not be mistaken for extravasation.* **(Right)** *The needle tip* ⇨ *overlies the patellofemoral joint on this lateral fluoroscopic radiograph obtained during lateral patellofemoral approach. Contrast flows away from the needle tip* ⇨*, consistent with intraarticular positioning.*

TERMINOLOGY

Definitions

- **Knee arthrography**: Injection of contrast medium into knee joint followed by imaging

PREPROCEDURE

Indications

- Postmeniscectomy knee evaluation
- Known/suspected hyaline cartilage defects
- Evaluation of osteochondral lesions

Contraindications

- Overlying soft tissue infection
- Coagulopathy

Getting Started

- Medications
  - 1% lidocaine for local anesthesia
  - Full-strength iodinated contrast
  - Gadolinium (MR arthrography)
  - Saline
- Equipment list
  - Standard arthrogram tray
    - Sterile, fenestrated drape
    - Local antiseptic solution
    - 18-g, 20-g, and 25-g 1.5" needles
    - 1-mL, 5-mL, 10-mL, and 30-mL syringes
  - Guidance equipment (fluoroscope)
  - Skin localizer: Metallic BB or other localizing instrument
  - Indelible marker

PROCEDURE

Patient Position/Location

- Patient supine with knee in either full extension or minimal flexion, toes pointing upward

Equipment Preparation

- Prepare contrast solutions
- MR arthrography
  - 1 30-mL syringe gadolinium, diluted 1:200 with normal saline
    - e.g., 0.15 mL of gadolinium and 30 mL of saline
  - 1 10-mL syringe of full-strength iodinated contrast
- CT arthrography
  - 1 30-mL syringe of 1:1 dilution full-strength iodinated contrast and normal saline

Procedure Steps

- **Lateral patellofemoral approach**
  - Gently sublux patella laterally, palpate lateral edge of patella, and mark skin at its midpoint
  - Using sterile technique, prepare and drape injection site
  - Administer local anesthesia with 1% lidocaine
  - While gently subluxing patella laterally, advance 20- to 22-g, 1.5" needle into joint, aiming for imaginary point in undersurface of center of patella
  - Needle tip should contact patellar cartilage
  - Once needle contacts patellar cartilage, aspirate fluid, if possible
    - Avoid overdilution of contrast from joint effusion
  - Inject small amount of iodinated contrast to confirm needle position
    - Contrast should flow away from needle
    - If contrast pools around needle tip, needle is not intraarticular and must be repositioned
  - Exchange syringe for syringe of dilute gadolinium (if MR arthrography) and perform contrast injection
    - Injection volume: ~ 30 mL
  - Obtain spot images (AP and lateral)
  - Wrap ACE bandage snugly over suprapatellar bursa
    - Optional; forces contrast from bursa into knee joint
- **Alternate: Anterior approach**
  - Useful in obese patients, when patella is not palpable, and in patients with severe patellofemoral osteoarthritis
  - Patient supine with knee in slight flexion, toes pointing upward
  - Localize inferior aspect of femoral trochlea, just medial or lateral to patellar tendon
  - Advance 20- to 22-g, 1.5" needle into joint until needle contacts femoral trochlea

Alternative Procedures/Therapies

- Radiologic
  - MR without arthrography
    - Generally, MR arthrography is more accurate than conventional MR in diagnosis of recurrent meniscus tears

OUTCOMES

Problems

- Extraarticular injection
  - Often, needle tip is too superficial; advance needle until it encounters bone
  - With patellofemoral approach, needle tip may be too posterior
    - Direct needle more anteriorly, aiming for undersurface of patella

Complications

- Most feared complication(s)
  - Infection (rare)
- Other complications
  - Pain after procedure
    - Usually transient, may persist several days
    - Treat with nonsteroidal antiinflammatory medications, acetaminophen
    - Benadryl often efficacious in treating pain

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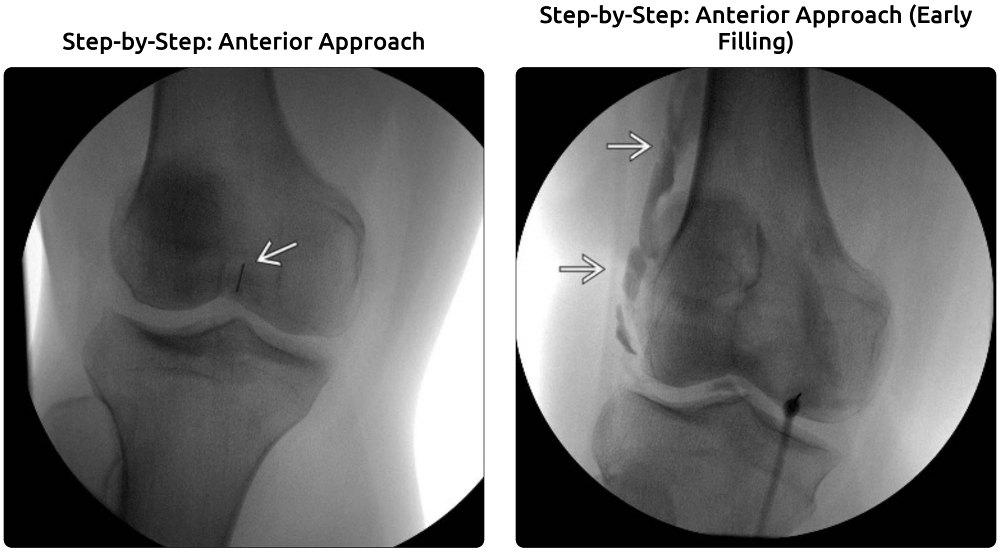
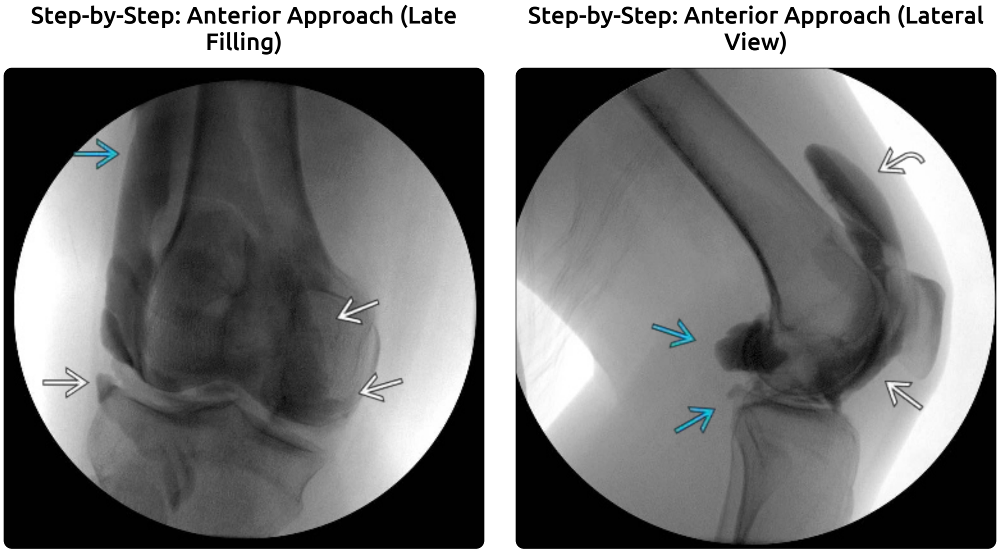


Step-by-Step: Anterior Approach

Step-by-Step: Anterior Approach (Early Filling)

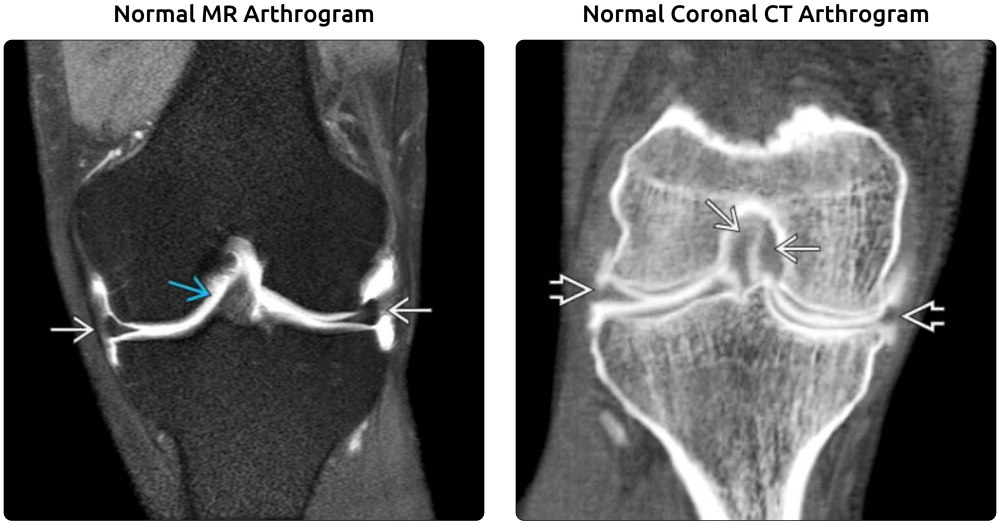
(Left) *Fluoroscopic spot radiograph demonstrates the ideal needle position for an anterior approach knee arthrogram with the needle tip* ➔ *overlying the femoral trochlea. This approach is often easier in obese patients, when the patella is not readily palpable.* **(Right)** *Anterior approach knee arthrogram demonstrates intraarticular contrast freely flowing away from the needle tip and extending into the suprapatellar bursa* ➔*.*



Step-by-Step: Anterior Approach (Late Filling)

Step-by-Step: Anterior Approach (Lateral View)

(Left) *Good joint filling is seen with contrast outlining the normal recesses of the joint* ➔ *and extending into the suprapatellar bursa* ⇨*.* **(Right)** *Lateral spot view demonstrates adequate joint filling, with contrast filling the anterior* ➔ *and posterior* ⇨ *recesses of the knee and extending into the suprapatellar bursa* ➔*.*

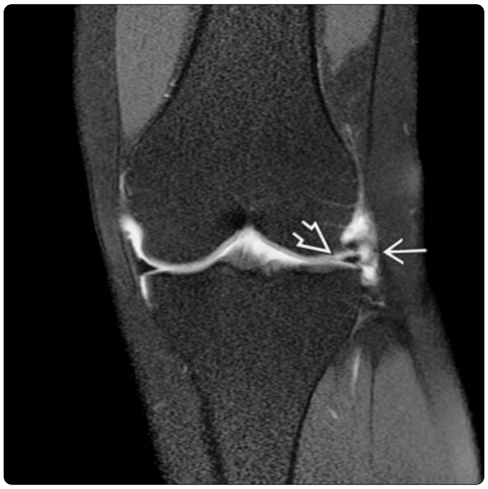


Normal MR Arthrogram

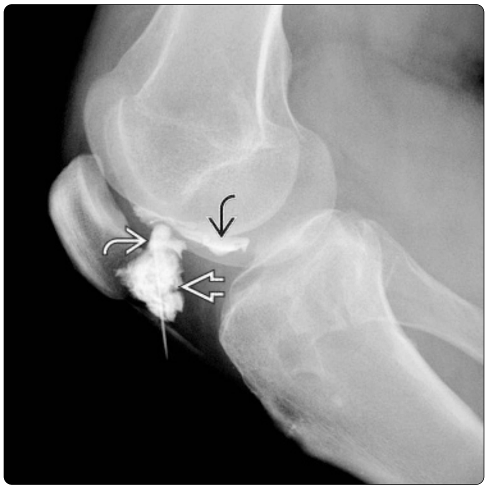
Normal Coronal CT Arthrogram

(Left) *Coronal T1 FS MR arthrogram shows contrast outlining the anterior cruciate ligament* ⇨ *and menisci* ➔*.* **(Right)** *Coronal CT arthrogram shows contrast surrounding the cruciate ligaments* ➔ *and the menisci* ➔*. Unlike MR arthrography, CT arthrography visualizes the intraarticular structures well only when they are surrounded by contrast. Good distention of the joint with contrast is the key to a diagnostic CT arthrogram.*

Lateral Meniscal Tear

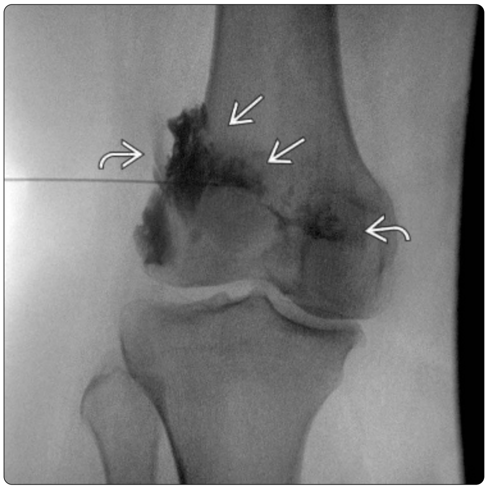


Extraarticular Contrast Injection

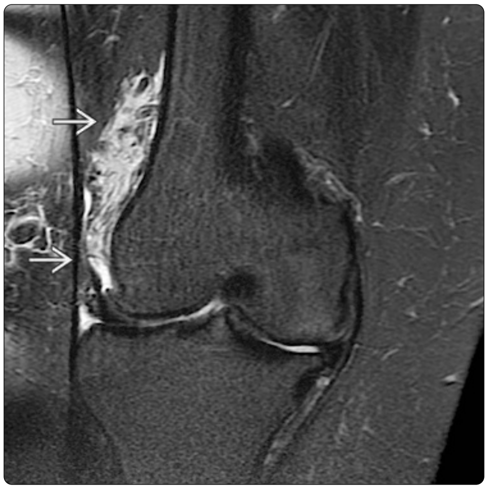


(Left) *Coronal T1 FS MR shows intraarticular contrast extending into a horizontal tear of the lateral meniscus ⇨ and into a parameniscal cyst →, which communicates with the meniscal tear.* **(Right)** *Lateral fluoroscopic spot radiograph shows that the needle tip ↪ is too low. Contrast is pooling in Hoffa fat pad ⇨. A small amount of contrast extends into the joint ↪, probably along the infrapatellar plica. Injection of Hoffa fat is quite painful.*

Mixed Injection

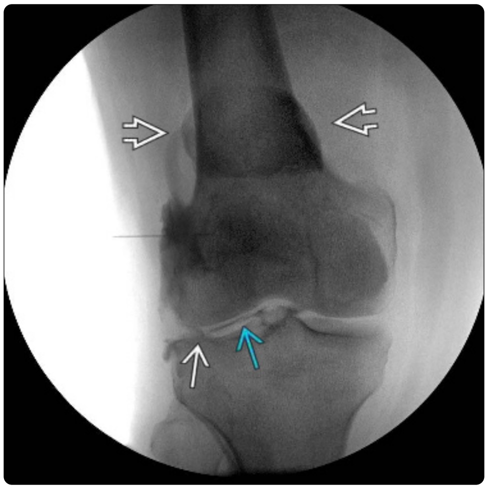


Mixed Injection

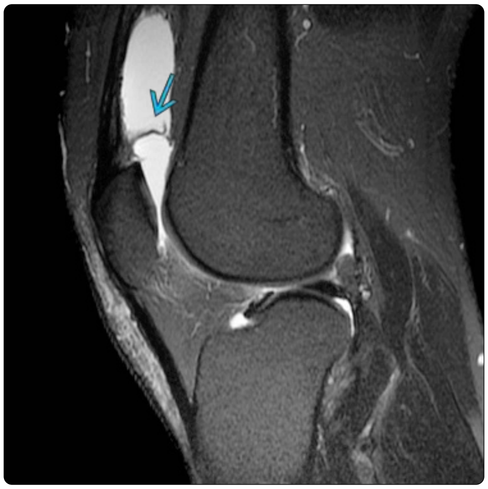


(Left) *AP knee arthrogram shows extraarticular contrast pooling around the needle tip and not conforming to the normal joint contours →. A small amount of intraarticular contrast is noted in the medial and lateral knee ↪.* **(Right)** *Coronal T2 FS MR in the same patient shows extraarticular contrast → in the fat along the lateral aspect of the femur.*

Superior Plica



Superior Plica



(Left) *AP knee arthrogram shows contrast collecting preferentially in the suprapatellar bursa ⇨ due to a superior plica. There is a small amount of contrast in the lateral compartment of the knee, outlining the cartilage → and lateral meniscus →.* **(Right)** *Sagittal T1 FS MR in the same patient demonstrates a band-like structure → between the knee joint and suprapatellar bursa, consistent with a superior plica. Synovial plicae are synovial folds and are thought to represent embryonic remnants.*

Ankle Arthrography

KEY FACTS

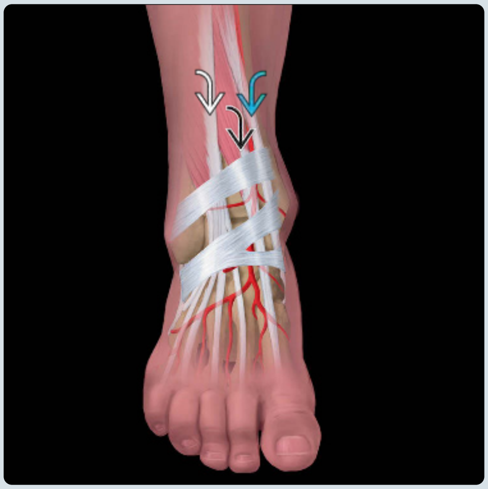
PREPROCEDURE

- Indications
    - Diagnostic: Primarily for assessment of osteochondral lesions &/or loose bodies
    - Therapeutic: Arthritis; pain relief

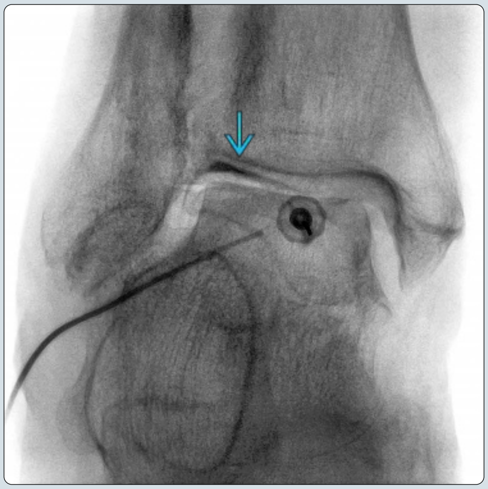
PROCEDURE

- Anterior approach, either with knee flexed and plantar surface of foot against table, or in lateral decubitus position
    - If equipment allows, ideal to be able to visualize needle intermittently in both AP and lateral projections
- Critical to palpate and avoid dorsalis pedis artery as well as the anterior ankle tendons
- Use 25-gauge needle, both for anesthesia and actual arthrographic injection
- Many potential entry sites exist
    - Medial to anterior tibial tendon
    - Medial to extensor hallucis longus
    - Between extensor hallucis longus and extensor digitorum longus
    - Medial or lateral clear spaces
- Enter skin just distal to joint, to avoid dorsal talar lip
    - Can angle needle cephalad, to place within joint spaces, or simply target talar dome, as this is intraarticular structure
- Filling of flexor hallucis longus tendon sheath or subtalar joint is normal variant
- CT arthrography preferable to MR arthrography if metal implants in ankle or in select cases for fine osseous detail
- Reporting findings
    - Report traditional MR findings, with particular attention to osteochondral lesions of talar dome, assessment of stable/unstable lesions, and loose bodies

(Left) *The anterior tibial* ⇨*, extensor hallucis longus (EHL)* ⇨*, and extensor digitorum longus (EDL)* ➡ *tendons are visualized along with the dorsalis pedis artery. These structures should be avoided at time of needle placement.* **(Right)** *An AP fluoroscopic image demonstrates anterior approach injection between the EHL and EDL tendons. Palpation and avoidance of the anterior ankle tendons and the dorsalis pedis artery are critical with this technique. Contrast injection confirms intraarticular needle placement* →*.*

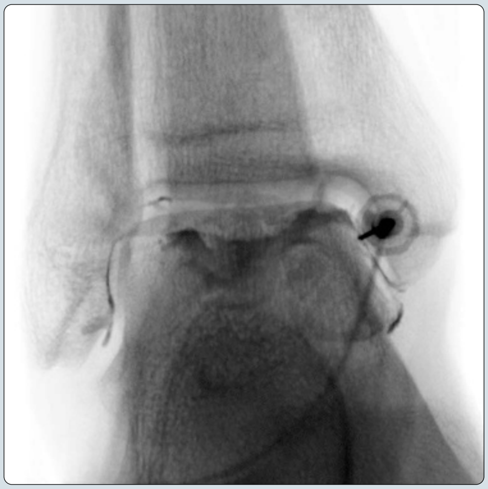


Anterior Ankle Tendons

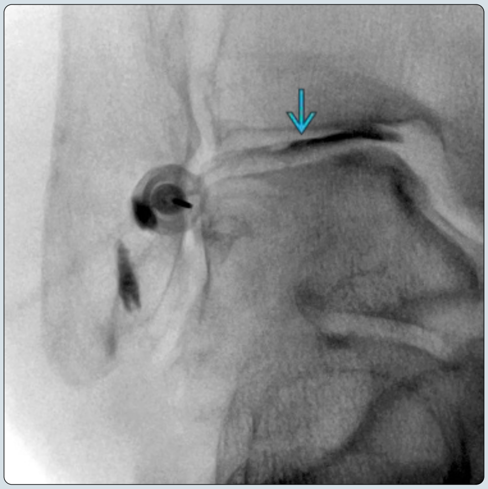


Anterior Approach Ankle Injection

(Left) *An AP fluoroscopic image demonstrates needle placement within the upper 1/2 of the medial clear space. This technique avoids the anterior tendons and dorsalis pedis artery.* **(Right)** *An AP fluoroscopic image demonstrates needle tip placement in the upper 1/2 of the lateral clear space with intraarticular contrast flow noted* →*.*



Medial Clear Space Injection



Lateral Clear Space Injection

PREPROCEDURE

Indications

- Diagnostic: Primarily for assessment of osteochondral lesions &/or loose bodies
  - Can also be performed for assessment of ligamentous injuries, although this can generally be accomplished by conventional MR
- Therapeutic: Arthritis; pain relief

Contraindications

- Infection overlying/involving needle entry site

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Anterior approach
- May be performed with patient in supine or lateral decubitus positions
  - Can place plantar surface of foot flat on table with knee flexed
    - Unaffected leg is bent and positioned proximal to side of interest
  - Fluoroscopy arm is rotated to provide AP or mortise view
  - Ideally, fluoroscopy rotatation will also allow for lateral view during procedure

Procedure Steps

- Sterilely prepare/drape target area as per routine
- Critical to palpate and avoid dorsalis pedis artery
- Use 25-gauge 1.5-inch needle for anesthetic and actual arthrographic injection
- Joint entered from anterior approach, via 1 of several options
  - Target talar dome, either medial to anterior tibial tendon, medial to extensor hallucis longus, or between extensor hallucis longus and extensor digitorum longus
    - Since anterior ankle capsule inserts on talar neck, contacting talar dome is intraarticular
    - Do not need to place needle actually between tibial and talar articular surfaces
  - Can also target medial or lateral clear spaces, while profiling ankle in mortise view
- Entry point ~ 1-2 cm below ankle joint, to avoid distal dorsal lip of tibia
- Advance needle into joint and inject small amount of contrast to confirm intraarticular location
  - Note: Tibiotalar joint may communicate with subtalar joint as well as flexor hallucis longus tendon sheath
- Inject contrast to distend tibiotalar joint, anywhere from ~ 2-6 mL

Alternative Procedures/Therapies

- Ultrasound
  - Particularly useful in setting of joint effusion &/or requested aspiration
  - Visualize and mark dorsalis pedis artery and extensor tendons
  - Localize anterior recess of joint, medial to anterior tibial tendon, and advance needle into joint
  - Can also target largest pocket of joint effusion directly, taking care to avoid major neurovascular structures

POST PROCEDURE

Post Procedure Imaging

- MR protocol
  - Patient supine, heel against gantry, toes vertical
  - Sagittal and coronal images usually best for cartilage abnormalities and assessment of osteochondral lesions
  - Coronal and axial images usually best for ligament injuries
    - Coronal images: Perpendicular to axis of talus
    - Axial images: Parallel to axis of talus
  - Need 1 plane of T1WI without fat saturation
    - Otherwise may not recognize marrow abnormalities, muscle atrophy
  - Perform combination of PD/T2 FS sequences and T1 FS sequences in all 3 planes
- CT protocol
  - CT arthrography preferable to MR arthrography if metal implants in/about ankle
    - Or potentially if ordering clinician/surgeon requests detailed osseous assessment
  - Millimeter or submillimeter slices with coronal and sagittal reformations
  - Review both soft tissue and bone kernel reformats

OUTCOMES

Problems

- Needle entry point too far cephalad
  - Looks well positioned on anteroposterior view
  - Lateral view shows needle blocked by anterior margin of tibia
- Contrast fills subtalar joint
  - Normal variant
  - If performing injection for pain relief, communication with subtalar joint could theoretically confound results in determining site of pain
- Contrast fills flexor hallucis longus tendon sheath
  - Normal variant

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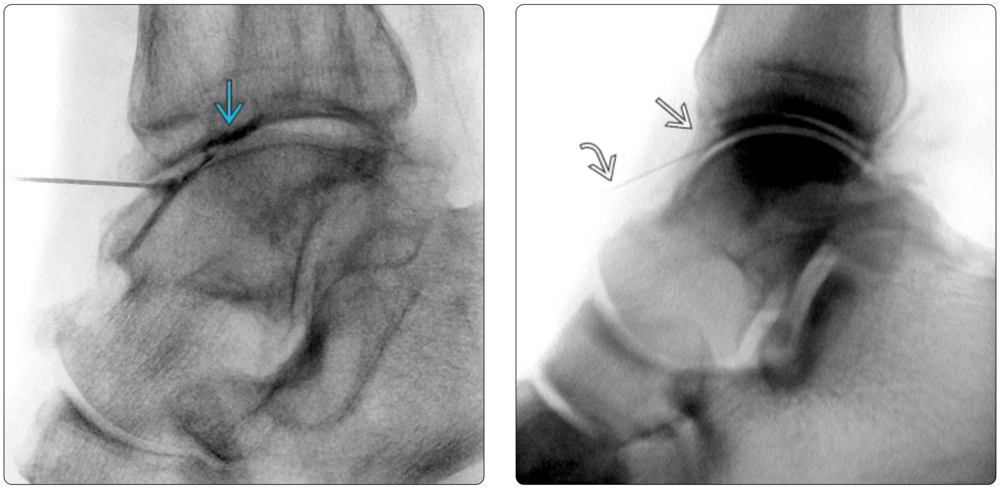
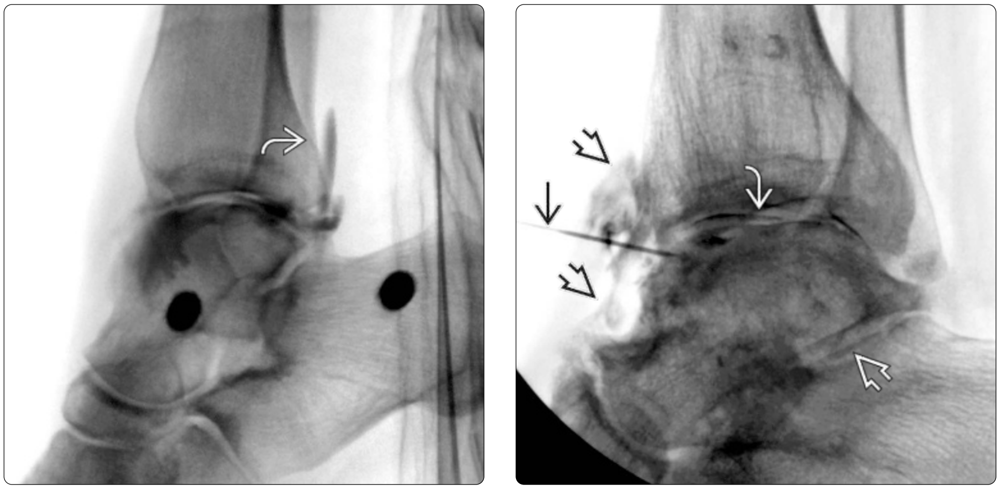


Needle Placement

Needle Placement, Angled Cephalad

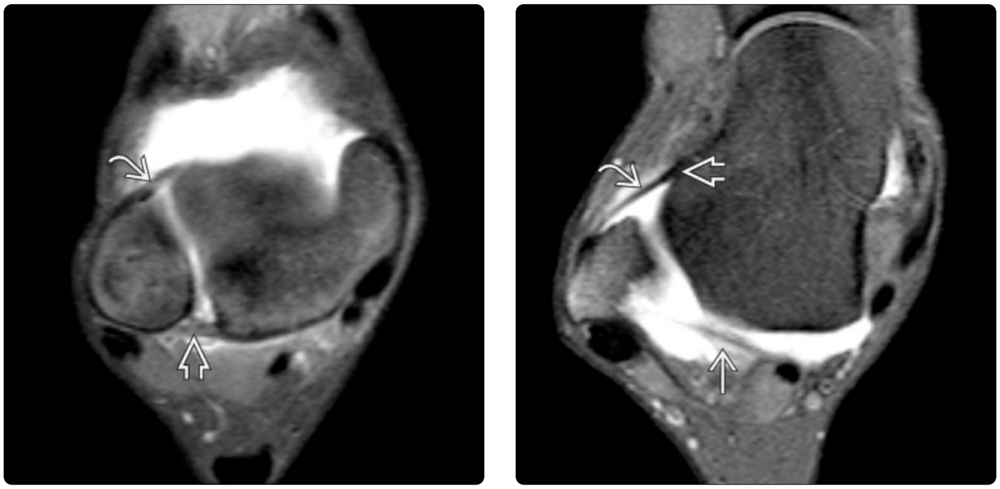
(Left) *Lateral view demonstrates the needle tip contacting that talar dome, which is an intraarticular structure. Contrast injection confirms intraarticular location →.* **(Right)** *Lateral arthrogram shows a needle → entering slightly inferior to the ankle joint and angled cephalad. This needle course avoids the dorsal lip of the tibia →, which can block needle entry if straight approach is used. Of note, needle tip can be placed directly between tibial and talar articular surfaces, as in this case, or at talar dome.*



Tendon Sheath Filling

Poor Needle Placement

(Left) *Lateral arthrogram shows normal filling of the FHL tendon sheath → after ankle injection. Filling of any other tendon sheath indicates malpositioned needle or ligament rupture.* **(Right)** *Lateral arthrogram shows poor needle placement. Needle entry point was too high →, resulting in initial extraarticular contrast injection →. Subsequent repositioning resulted in intraarticular injection →. Filling of the posterior subtalar joint → is a normal variant seen in ~ 15% of patients.*

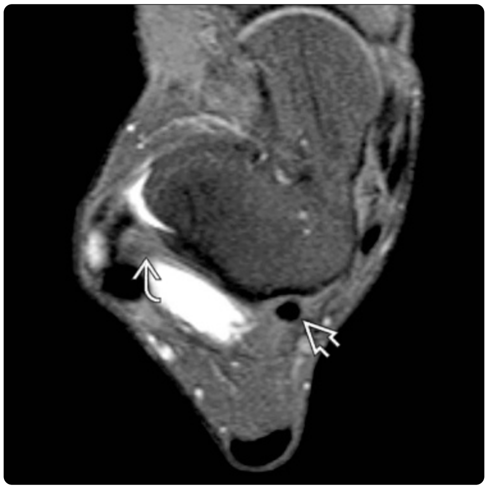


Normal MR Ankle Arthrogram (Axial)

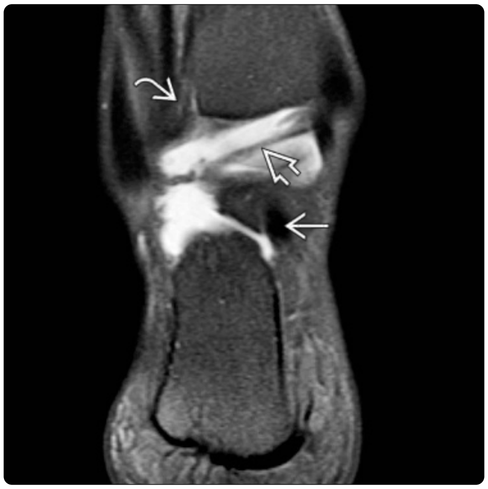
Normal MR Ankle Arthrogram (Axial)

(Left) *Axial MR after arthrography shows normal anterior → and posterior → tibiofibular ligaments, immediately superior to the tibial plafond. The anterior joint recess is well distended. There should be no posterior joint recess at this level.* **(Right)** *Axial T1WI FS MR after arthrography shows a normal anterior talofibular ligament →, which attaches to the superolateral corner of the talar neck →. A portion of the intermalleolar ligament → is also seen.*

Normal MR Ankle Arthrogram (Axial)

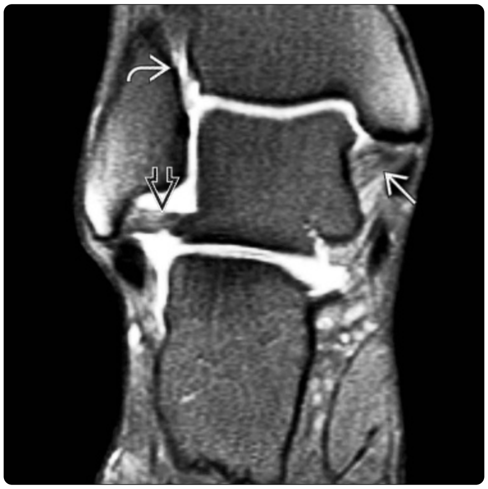


Normal MR Ankle Arthrogram (Coronal)

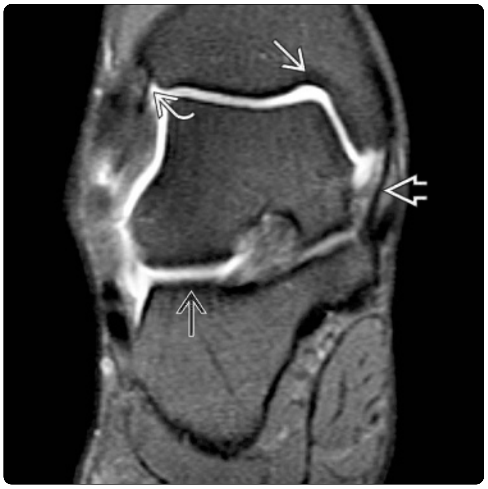


(Left) *Axial T1WI FS MR obtained following arthrography shows a normal posterior talofibular ligament ↪, which is rarely torn. The FHL ⇨ tendon sheath sometimes fills with contrast, although filling is not seen here.* **(Right)** *Coronal T1WI FS MR obtained after arthrography shows a normal posterior tibiofibular ligament ↪ and a normal intermalleolar ligament ⇨, sometimes called the transverse ligament. The FHL tendon → is seen adjacent to the joint.*

Normal MR Ankle Arthrogram (Coronal)

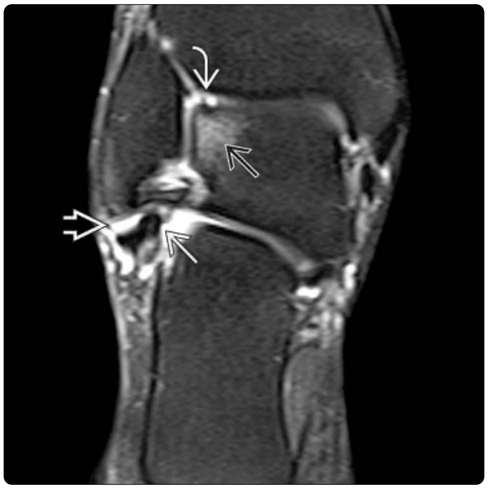


Normal MR Ankle Arthrogram (Coronal)

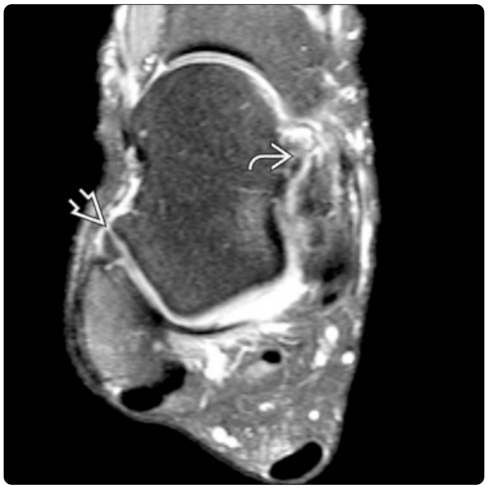


(Left) *Coronal T1WI FS MR arthrogram shows normal deltoid → and posterior talofibular ⇒ ligaments. Contrast medium extends into normal syndesmotic recess ↪.* **(Right)** *Coronal T1WI FS MR after arthrography shows a normal anterior tibiofibular ligament ↪. The tibiocalcaneal band ⇨ of the superficial deltoid ligament is seen medially. Note the normal filling of the subtalar joint ⇒. A focal concavity in the medial tibial plafond → is normal.*

Abnormal MR Ankle Arthrogram (Coronal)



Abnormal MR Ankle Arthrogram (Axial)



(Left) *Coronal PD FS MR arthrogram demonstrates small cartilaginous defect ↪ with adjacent bone marrow edema ⇒ along the talar dome. Torn calcaneofibular ligament ⇨ is also noted. Contrast extends through the torn ligament and around the peroneal tendons →.* **(Right)** *Axial MR arthrogram demonstrates a chronic anterior talofibular ligament tear ⇨, which forms a meniscoid lesion that may result in anterolateral ankle impingement. The superficial deltoid ligament is also torn ↪.*

Foot Arthrography

KEY FACTS

PREPROCEDURE

- Procedure indications
  - Most foot injections are therapeutic
  - Useful to treat and identify source of pain

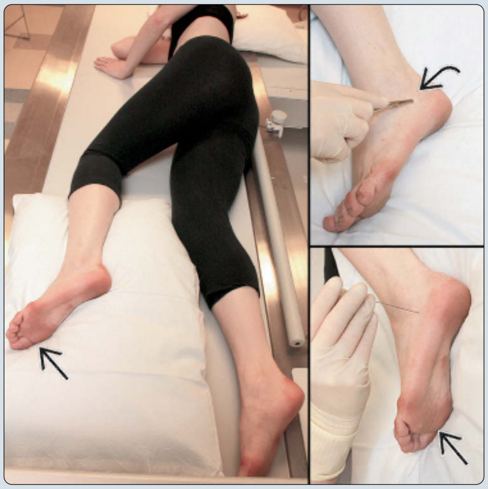
PROCEDURE

- Position patient to place joint in profile
  - Place towels under foot as needed
- Use same 25-g needle for superficial anesthesia and joint injection
- Joint volumes are small; do not overdistend
  - Use small amount of contrast (0.5 mL or less) to confirm needle in joint prior to therapeutic injection
- Use high-concentration corticosteroid in small volume, in tuberculin syringe for accurate dose measurement
- Inject corticosteroid first; follow with long-acting anesthetic if sufficient space
- Do not overdistend joints
  - Have patient tell you when joint feels full
- **Findings and reporting**
  - Degree of pain relief, variant communications between joints

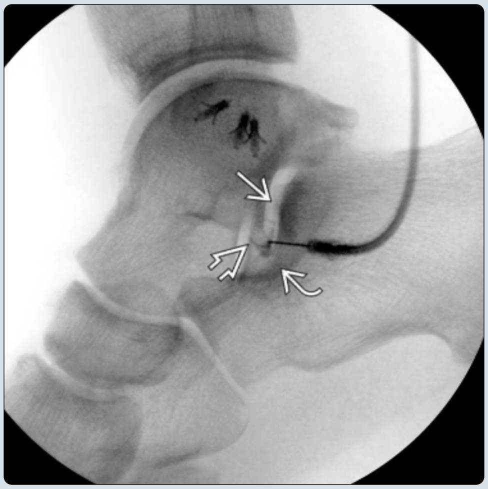
OUTCOMES

- Problems
  - Osteophytes may block injection
    - Especially midfoot
  - En face osteophytes often poorly seen on fluoroscopy
    - Turn foot or fluoroscope to see and avoid osteophytes
- Complications
  - Most feared complication
    - Infection (rare)

Posterior Subtalar Joint Injection: Patient Positioning

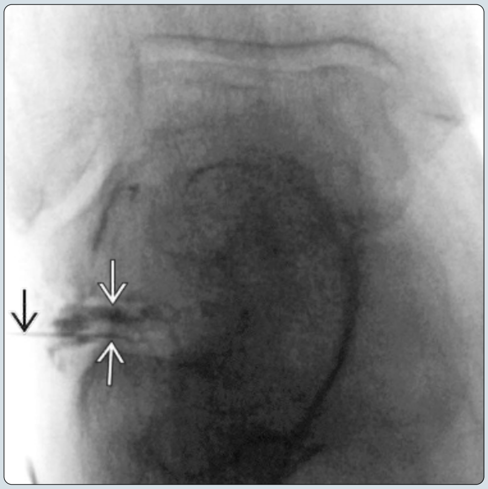


Posterior Subtalar Joint Injection

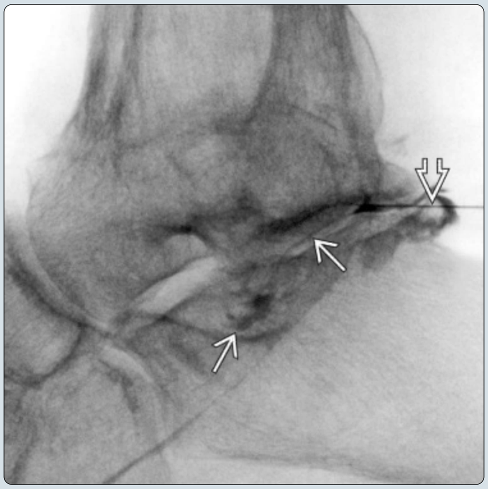


(Left) *Photograph shows positioning of a patient for a posterior subtalar joint injection. The foot is not in a true lateral projection, but the toes* → *project slightly downward. This brings the lateral portion of the joint* ↪ *into profile.* **(Right)** *Arthrogram shows a needle between the tip of the lateral talar process* ⇨ *and the calcaneal angle of Gissane* ↪*. The needle is inferior and slightly anterior to the fibular tip. Contrast flows from the needle tip into the joint* →*.*

Posterior Subtalar Joint Injection



Posterior Subtalar Joint Injection: Alternate Access



(Left) *AP arthrogram shows a needle* → *entering the posterior subtalar joint and contrast outlining the joint surfaces* →*. An AP view can be used to confirm needle position but is not advised for guiding initial needle placement.* **(Right)** *Lateral arthrogram shows a needle* ⇨ *at the posterolateral portion of the posterior subtalar joint in a patient whose bulky lateral bone graft blocked the usual injection site. Contrast* → *outlines the joint.*

TERMINOLOGY

Definitions

- **Foot arthrography**: Image-guided injection of contrast into foot joint(s)

PREPROCEDURE

Indications

- Most foot injections are therapeutic

Getting Started

- Things to check
  - Review of any prior pertinent imaging
  - Written informed procedural consent
  - Allergies
- Medications
  - **Anesthetic agents**
    - 1% preservative-free lidocaine
    - 0.5% ropivacaine
  - **Corticosteroid**: For therapeutic arthrogram
    - Use high-concentration corticosteroid in small dose (small joint volumes in foot)
      - e.g., 80 mg/mL methylprednisolone acetate; use 20-25 mg for small joints
- Equipment list
  - Nonionic iodinated contrast
  - Standard arthrogram tray
  - Skin localizing device

PROCEDURE

Patient Position/Location

- Best procedure approach
  - Position patient to place joint in profile
  - Use towels under foot to place it in optimal position

Equipment Preparation

- Use same 25-g needle for superficial anesthesia and joint injection

Procedure Steps

- Inject minimal (< 0.5 mL) iodinated contrast to document correct needle placement
  - Joint capacities in foot are small; must leave adequate space for steroid &/or anesthetic
- Inject corticosteroid, given small joint volumes; follow with long-acting anesthetic (0.5% ropivacaine) if sufficient space
- **Subtalar joints**
  - Articulation between talus and calcaneus
    - Divided into anterior and posterior subtalar joints, which do not communicate
      - Anterior subtalar joint has anterior and middle facets and communicates with talonavicular joint; sometimes referred to as talocalcaneonavicular joint
      - Posterior subtalar joint has only posterior facet; posterior subtalar joint may communicate with tibiotalar joint in minority of patients
  - **Posterior subtalar joint** (lateral approach)
    - Place patient in lateral decubitus position
    - Lateral aspect of affected foot side up, foot supported on towels
      - Place pillow under knee as needed
    - Adjust rotation of foot until lateral process talus and angle of Gissane (formed by downward and upward slopes of superior calcaneal surface) clearly seen
    - Advance needle between tip of lateral process and angle of Gissane
    - Can confirm location on AP or mortise view
  - Injection volume: 3-4 mL
  - **Anterior subtalar (talocalcaneonavicular) joint**
    - Place patient supine
      - Knee bent with foot flat on fluoroscopy table
    - Localize between talus and navicular on AP view
    - Contrast flow into subtalar joint often seen best on lateral view
    - Injection volume: 3-4 mL
- **Calcaneocuboid joint**
  - Position as for posterior subtalar joint
  - Rotate foot until joint in profile
    - Usually achieved with slight internal rotation
  - Injection volume: ~ 1 mL
- **Naviculocuneiform joint**
  - Place patient supine
    - Knee bent with foot flat on fluoroscopy table
  - Localize for injection between navicular and 1st or 2nd cuneiform on AP view
  - Injection volume: ~ 1 mL
- **Tarsometatarsal (TMT) joint**
  - Place patient supine
    - Knee bent with foot flat on fluoroscopy table
  - If using C-arm, angle beam slightly to catch joint in optimal profile
  - 3 separate joint capsules
    - 1st TMT: Inject at center of joint
    - 2nd-3rd TMTs: May inject either ray; access where less severe osteoarthritis allows easier joint entry
    - 4th-5th TMTs: Turn foot to internal oblique position, inject either ray
  - Injection volume: ~ 1 mL
- **Metatarsophalangeal (MTP) joints**
  - Place patient supine
    - Knee bent with foot flat on fluoroscopy table
  - Center needle just proximal to joint and angle distally, under dorsal edge of proximal phalanx
  - 1st MTP joint injection volume: 1.0-1.5 mL
  - 2nd- 5th MTP joint injection volumes: < 1 mL

Findings and Reporting

- Degree of pain relief achieved
- Any variant communications between joints

Alternative Procedures/Therapies

- Radiologic
  - Ultrasound-guided injection

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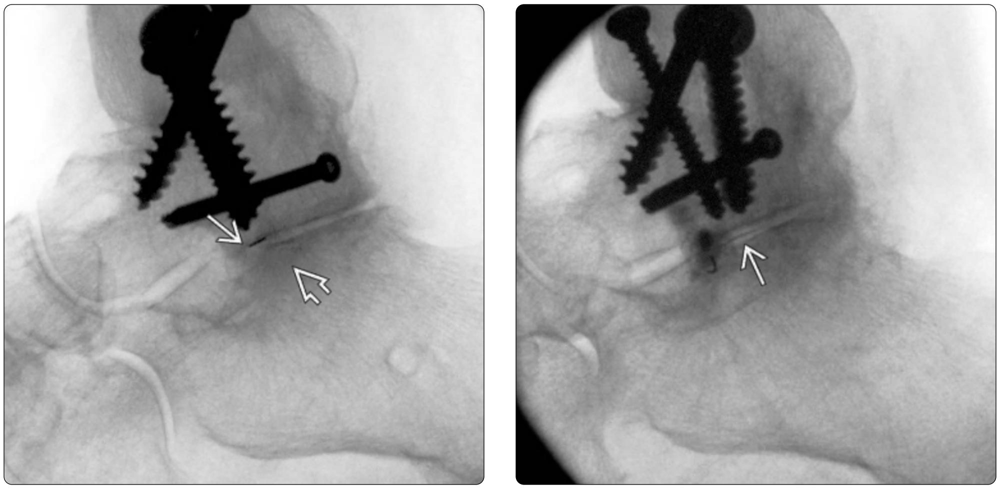
1. Newman JS: Diagnostic and therapeutic injections of the foot and ankle. Semin Roentgenol. 39(1):85-94, 2004
2. Ruhoy MK et al: Subtalar joint arthrography. Semin Musculoskelet Radiol. 2(4):433-438, 1998

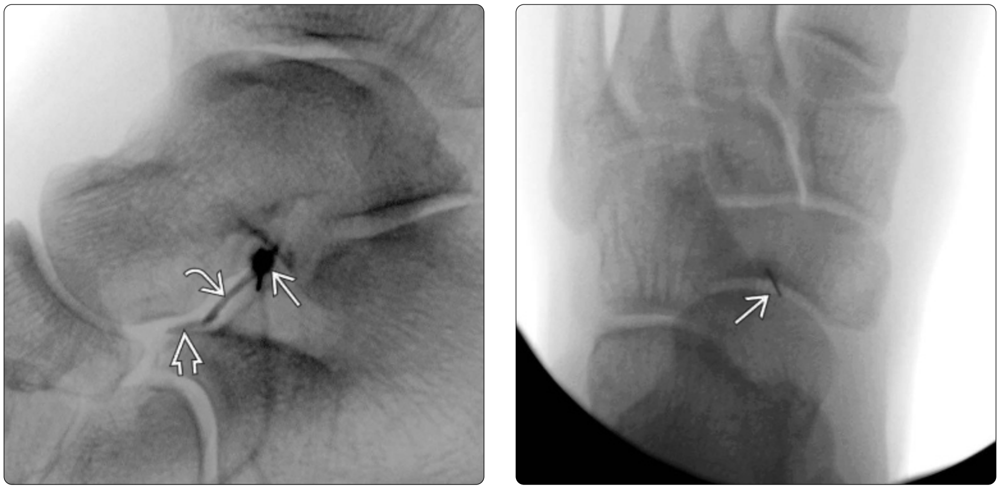
(Left) *Lateral arthrogram shows a needle → that appears to overlie the posterior subtalar joint. However, because foot is obliquely positioned, the smaller, more horizontal, medial portion of the joint is in profile, not the posterior portion of the joint. Contrast ⇨ puddles adjacent to joint.* **(Right)** *After slight repositioning of the foot and needle position, a lateral arthrogram shows contrast → is now intraarticular. Correct positioning is critically important for posterior subtalar joint injection.*



Posterior Subtalar Joint Injection: Extraarticular Needle Placement

Posterior Subtalar Joint Injection: Correct Needle Placement

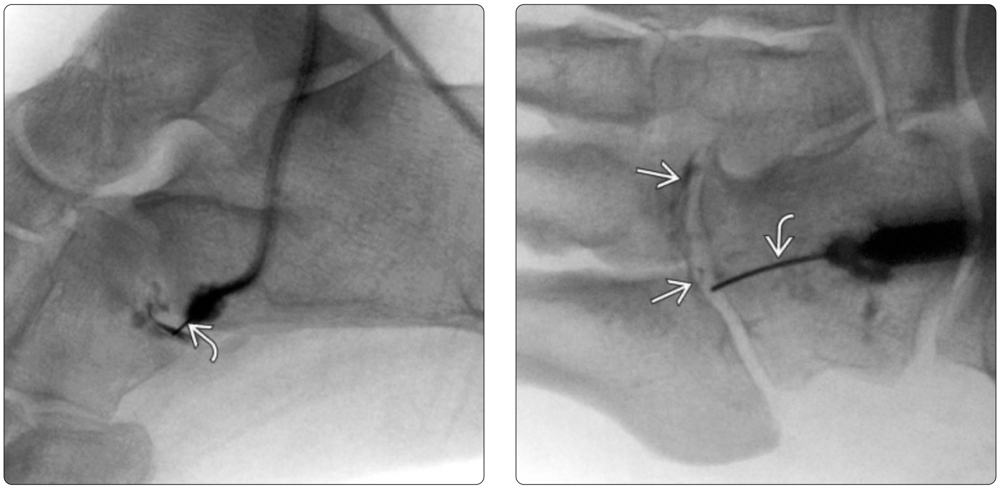
(Left) *Lateral arthrogram shows a needle → in the middle facet of the anterior subtalar joint. Contrast outlines the joint ↪ and extends into the contiguous anterior facet ⇨.* **(Right)** *AP arthrogram shows needle → in the talonavicular joint. The talonavicular joint communicates with the anterior subtalar joint. Thus, the easiest way to inject the anterior subtalar joint is through a talonavicular joint injection.*



Anterior Subtalar Joint Injection

Talonavicular Joint Injection

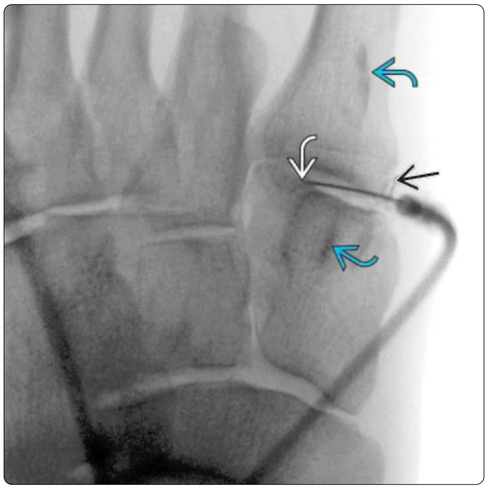
(Left) *Lateral arthrogram shows needle ↪ placement at the inferior calcaneocuboid joint margin where a joint recess is present, and the joint is often easiest to access. The foot is in an oblique lateral position.* **(Right)** *Oblique arthrogram shows needle ↪ placement in the 5th tarsometatarsal (TMT) joint, outlining the common cavity of the 4th and 5th TMT joints →. The foot is placed in an oblique position in order to eliminate overlap of the 3rd TMT joint.*



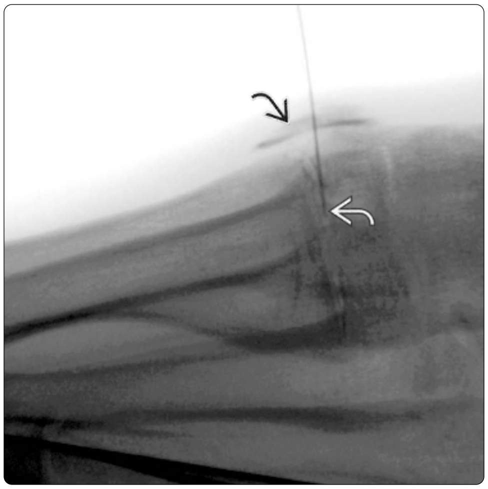
Calcaneocuboid Injection

Tarsometatarsal Joint Injection

1st Tarsometatarsal Joint Injection

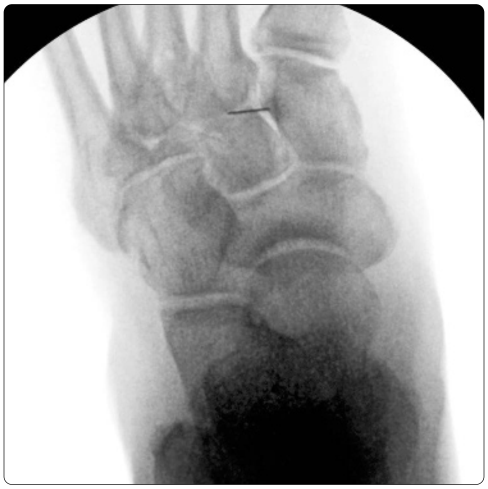


1st Tarsometatarsal Joint Injection

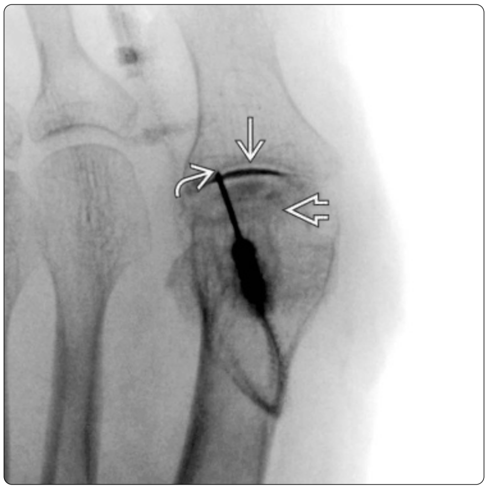


(Left) *AP arthrogram shows the appropriate position of the needle tip* ↪ *in the 1st TMT joint. The initial injection was into the extensor tendon sheath* ↪*, dorsal to the joint. The needle was advanced, and on the 2nd attempt, the contrast followed the joint contour* →*.* **(Right)** *Lateral arthrogram in the same patient shows the initial contrast in the extensor tendon sheath* ↪ *and confirms a satisfactory needle position* ↪ *in the joint.*

2nd Tarsometatarsal Joint Injection

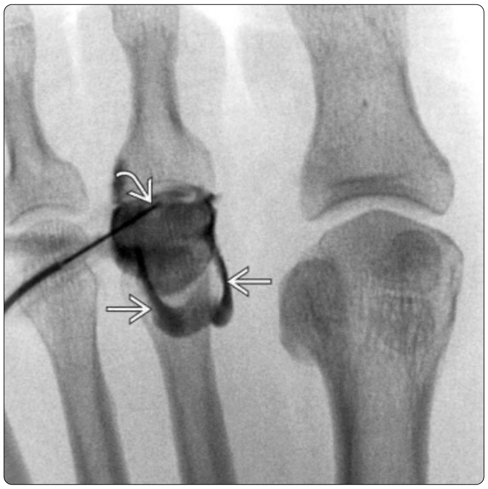


Hallux Limitus Due to Osteophytes

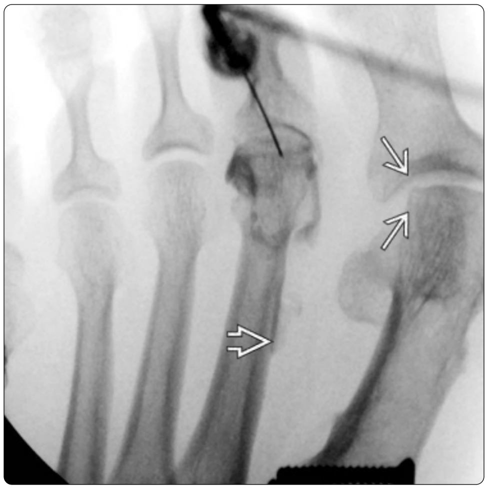


(Left) *AP arthrogram shows needle in the 2nd TMT joint. The fluoroscopy tube has been tilted to show the joint in profile. The 2nd and 3rd TMT joints have a shared joint cavity, and needle can be placed at either articulation for injection.* **(Right)** *AP arthrogram shows needle placement* ↪ *in the 1st metatarsophalangeal (MTP) joint and contrast* → *outlining the articular surfaces. Large dorsal osteophytes* ⇨ *are not well seen because they are en face. The needle was gently "walked" past the osteophytes until it slipped into the joint.*

Metatarsophalangeal Arthrogram



Plantar Plate Rupture



(Left) *AP arthrogram shows a needle* ↪ *in the 2nd MTP joint and contrast filling a normal joint and plantar recesses* →*. The needle can be placed through or adjacent to the extensor digitorum tendons.* **(Right)** *AP arthrogram shows contrast extravasation along the flexor tendon sheath* ⇨*, indicating rupture of the plantar plate. This occurs in patients who have increased stress on the 2nd toe. Note the short 1st metatarsal, metatarsus primus varus, and hallux valgus* → *deformities, causing stress transfer to the 2nd toe.*

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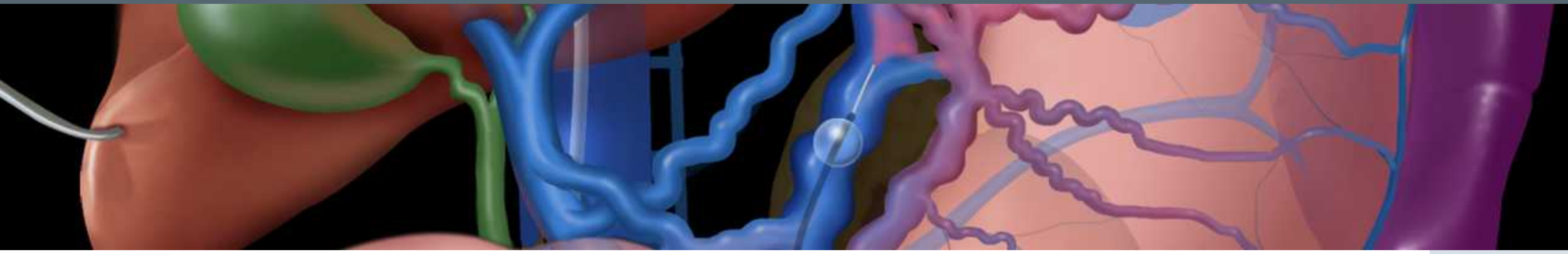

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